HIGHWAY RESEARCH RECORD

Number 401

Intermodal Transportation Planning at the State, Multistate, and National Scale

7 reports

HIGHWAY RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING

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Intermodal Transportation Planning at the State, Multistate, and National Scale

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FOREWORD

The formation of state departments of transportation has resulted in an increased interest in statewide transportation planning. This interest is reflected in the papers contained in this RECORD.

Hand states that state development policies and planning, including transportation, need to reflect a common base of population, economic, and resources information and analysis; state government needs to be encouraged to move more in the direction of a goals definition that is part of a systematic consideration of overall objectives, targets, needs, deficiencies, implementing programs and projects, and periodic recycling of these judgments.

Wilson discusses the current and future intermodal transportation planning in Tennessee. The author states that intermodal planning gained emphasis at the state level during the completion of the National Highway Functional Classification and Needs Study. Future intermodal planning in Tennessee will be enhanced according to the author as the long-range priorities and programming techniques are evaluated and modified and a statewide data bank is developed.

Hoel and Sauerlender describe elements in a program of statewide comprehensive transportation that were recommended for implementation by the Pennsylvania Department of Transportation. The first part describes the elements of the statewide transportation planning process and the specific modeling tasks that were identified, and the second part describes the regional model for forecasting the flow of freight.

Creighton and Hamburg state that the position of statewide transportation planning in 1972 has advanced to about the position of urban transportation planning in 1955. To improve this position, the authors state, we have the advantage of knowing a great deal more about the planning processes, goals, simulation, data collection, and evaluation. The paper is based on the authors' current work for the state of Pennsylvania, the Traffic Engineering Handbook, and the National Cooperative Highway Research Program.

Mongini in his paper emphasizes the relation between national and state transportation planning. He states that at both levels of government new emphasis has been placed on the ability to consider all modes of transportation, if not through the same analytical techniques, at least through the same planning process and with the same organizations. The example used by the author in discussing the interrelations of national and state transportation planning is the National Transportation Study.

Breuer presents an updating of the New York statewide planning program reported at the 1969 HRB meeting. The author states that policies and plans for transportation in New York State are currently being updated. This effort will be more than a map of new capital facilities with concern for resource allocation between highways and public transportation, between urban and rural programs, and between capital and operating assistance—all being represented in the updating process. Also, the new plan will make specific recommendations for state policies and actions as well as the operation of the transportation system.

Hazen reviews 5 statewide transportation studies undertaken by Iowa, Wisconsin, Rhode Island, Connecticut, and California. For each study the procedures, strong points, and limitations are described. The studies are compared and rated as to the amount of effort expended in study design, data collection and design, model development, forecasting, testing of alternatives, and implementation.

STATE DEVELOPMENT POLICIES AND PLANNING

Irving Hand, Pennsylvania State Planning Board

•THE Washington Center for Metropolitan Studies, in a 1970 report prepared for the Urban Mass Transportation Administration (1), observed that "...state planning is an institutional jungle." The report stated that states making efforts to innovate and to plan comprehensively find this is a difficult task and that, although the powers of the states are great, state planning tends to be constrained by unmanageable bureaucracies and out-dated laws.

The Center further stated that, when planning is instituted at the state level, basic questions should be addressed about the functions and purposes of planning—questions that are complex both in their abstractions and in their applications and are not easy to answer. For example, putting "urban affairs" into operating departments has advantages organizationally, but the disadvantage is the burden caused by weaknesses in program management and goal development for the whole state.

All of the fundamental questions about the position and the role of planning in government not only arise in state planning but also are perhaps more difficult to answer. Is planning essentially an on-going process that should encompass all of government? Does it have specific programmatic concerns such as housing or public transit? Should there be a state "plan"? If there is, what does it mean and how is it to be used?

States potentially hold great powers over development. In the past, many judge that these powers have not been exercised in systematic or coherent ways. Obsolete administrative structures, unresponsive legislatures, weak governors, and restrictive constitutions have inhibited positive roles the states might play.

Notwithstanding some of the newspaper stories (2, 3, 4) following the 1971 National Governors Conference in Puerto Rico, there are signs that change is overtaking state governments and that they are beginning to respond and exercise their powers in more meaningful ways. There are signs of movement toward a period of "creative statehood," and that period should witness various approaches to the fulfillment of state responsibilities. If this is the case, state planning will take on new shapes and purposes and may become more significantly involved in state strategy formulation and expression.

Except in those instances, however, and perhaps even including where there is strong gubernatorial or key legislative leadership, a great deal will still depend on the understanding of federal institutions and bureaucracies. For example, within the context of the Intergovernmental Cooperation Act and Office of Management and Budget Circular A-95, the federal government will play a major role in determining whether state planning will become comprehensive and an effective tool of general state government or become merely a guideline "requirement" of specific functional programs, interpreted as another limited ritual to be performed in return for a federal grant.

Administrative reorganizations and constitutional revisions are undoubtedly strengthening the hands of governors. Increasing state fiscal responsibility and participation in a variety of functions implies a sense of coordination and the application of a central, comprehensive intelligence. But how are housing, transportation, economic development, and antipoverty efforts legislatively or managerially linked? Does each function tend to plan and act for itself? How effectively have state agencies planned and programmed together?

A consideration of state development policies and planning advisedly might take into account, as well, the judgments expressed by Tomazinis (5). He forecasts that a completely new era is about to commence in urban transportation and notes that, after years of (fruitless) efforts, it seems widely accepted today that, although transportation is perhaps the most important single factor in land development, the remaining

factors are many indeed and far exceed the single transportation factor in importance. As a result, professionals in the field and in governmental agencies responsible for the production and implementation of transportation planning and plans, especially in urban areas, need to adapt and improve both the plans they recommend and the process by which they study the problems and derive their conclusions.

Reflecting recent legislation, court actions, and experience with citizen groups, Tomazinis suggests several principles that are directly addressed to transportation planning but that offer insights into the usefulness of other elements of functional planning and are not without reference value to comprehensive planning as well:

1. The plan must meet the travel needs and provide for present and future travel demand of all population groups and sectors of the economy;
2. The plan must bear the absolutely minimum negative environmental impacts to the region as a whole and the specific localities and communities of the region;
3. The plan must provide for the maximum opportunities for the achievement of social goals and objectives that are in any way associated and facilitated by the transportation systems and at the same time strive to reduce by all feasible means the negative social impacts the plan may have;
4. The plan must be economically feasible, must minimize the total economic burden it imposes on the society, and must distribute its costs and benefits in a manner acceptable socially and economically; and
5. The planning process must be participatory and involve essentially the various governmental units of the region and the various population groups that make up the region.

Against the perspective of these observations, it is interesting to note some of the discussion in the 1969 State Legislative Program proposed by the Advisory Commission for Intergovernmental Relations as it dealt with state and regional planning.

> The increasingly complex responsibilities of State government have created a need for strong, well-staffed, strategically located planning services to assist in formulating short and long-term State goals and needs and an inventory of resources for meeting them. The sophisticated task of relating innumerable programs and policies to one another and to those of other levels of government is a responsibility that States cannot avoid.
>
> The vital need for such a planning capability is nowhere more clearly illustrated than by the problems arising from the increasing concentrations of population in urban areas, the plight of rural communities, and the attendant difficulty of matching needs for public services with available resources. While Federal grant-in-aid programs represent the major current national effort to assist the State and local governments, the constantly increasing number and complexity of grant programs frequently have served as an impediment to their effective utilization. These developments clearly underscore the need for a strong State and regional planning capability.
>
> Governors and State legislatures must be able to allocate current resources among a number of competing needs through the budgetary and appropriation process. They need to analyze and assess the impact of individual programs on one another and to anticipate emerging problems and demands. These responsibilities require the closest relationship between highly qualified budget and planning staffs and call for a continuing, close, functioning relationship.
>
> The need is increasingly recognized for a planning organization and for planning procedures capable of developing urbanization policies for the States and relating the complex Federal grant programs to one another and to State and local activities and resources. There is a pressing need for a method of coordinating departmental plans, many of which are required by Federal grant legislation as a condition for receiving funds. Yet most States do not have an effective means of coordination, and in only one-third of the States are State agencies required to obtain the approval of the governor prior to submitting applications for Federal grant assistance. The necessity of relating those grant-assisted local projects and programs which have a significant impact outside their own borders to areawide needs and objectives and to State plans and policies is still another complicating factor. Federal legislation now requires review of urban development grant applications from metropolitan areas either by a metropolitan-wide or State agency and State offices of planning are sometimes assigned a coordinative role for the utilization of Federal funds by both State agencies and their local units. However, effective planning and coordination often still is lacking. [One should note that the Intergovernmental Cooperation Act and OMB Circular A-95 is attempting to carry this forward in more positive terms.]

Not only do States have a responsibility for coping with urbanization after it has taken place; they also have a responsibility to plan for urbanization to come. The States need to act rather than merely to react. For States to fulfill their key role in the development of urbanization policy they must have a planning process that will develop the policies needed to channel and guide the growth of the State. The States through their constitutions and statutes determine the general outline and many of the details of the specific structure, form, and direction of urban growth. They should supply guidance for specific local government, metropolitan, and multicounty planning and development programs. They should establish a link between urban land use and development oriented local planning efforts and broader regional and national objectives. Although the evolution of effective State planning can be seen in a few States, it is doubtful if planning in any State government has arrived yet at a stage adequate for assuming its appropriate role in the development of State land use and urbanization policy.

Two reports of the Advisory Commission on Intergovernmental Relations include consideration of this problem and recommend that each State develop a strong planning capability in the executive branch of its State government. The Commission recommends that the planning function include formulation for consideration by the governor and the legislature of comprehensive policies and long-range plans for the effective and orderly development of the human and material resources of the State, including specifically plans and policies to guide decisions which affect the pattern of urban and social growth. The provision of a framework for coordinating functional, departmental, regional, and local plans is recommended. Further a method of formal review of State, regional, and local plans and projects and, where relevant, local implementing ordinances for their conformity with State urbanization plans and policy is recommended. More specifically, it is urged that multicounty planning agencies be assigned responsibility for reviewing applications for Federal or State physical development project grants from constituent local jurisdictions and that provision be made for review and comment on all local and areawide applications for urban planning assistance. Finally, it is recommended that State legislatures provide within their standing committee structure a means to assure continuing, systematic review and study of the progress toward the State urbanization policy.

A framework for state planning that emerges from a consideration of the ACIR model State and Regional Planning Act and from a consideration of the efforts in a number of states during the past several years suggests an emphasis on the management of resources within a short-range and long-range context. This implies the formulation and expression of policies and plans in some fashion.

When we take a look at the track record and find the cupboard not brimming over with "goodies," a couple of observations come to mind. One relates to the adequacy of the resources: money, manpower, information, and capability to do the job. The other relates to whether the case for planning is based on rhetoric or leadership (and public) conviction that policies, plans, and planning are essential to the decision-making processes of a complicated society.

A conference on organization for continuing urban transportation planning held by the Highway Research Board in late 1971 experienced some tough discussions in dealing with these points that are crucial not only to the organization but also to the very substance of continuing urban transportation planning. The relative role, support, and use of comprehensive planning in some reasonable comparison with transportation planning generated heat as well as (we hope) light; arguments as to process versus product, particularly within a context of planning as a management tool, were warm as well.

In Pennsylvania, the Appalachian Program and the Federal Land and Water Conservation Act, both enacted in 1965, have been instrumental in gaining a recognition for statewide development policies and planning.

The Appalachian Program stimulated a consideration of 52 of Pennsylvania's 67 counties (half of the people and three-fourths of the geography) that may be too dominated by past trends. Nevertheless in 1968, we produced a first cut at a state development plan in connection with projects funded in whole or in part by the program. It took an interstate, a statewide, and a multicounty regional interplay that had not previously occurred to produce this expression of direction, priorities, and projects. On the basis of this experience, we undertook a somewhat similar examination of the state's southeastern 15 counties, and that experience was eloquent commentary on the adequacy—or inadequacy—of our information and capability to deal with highly complicated and personally and politically sensitive issues and questions.

The Federal Land and Water Conservation Act, along with 2 state programs (Project 70 and Project 500), has revealed the achievability of expression of development policy and planning. A statewide outdoor recreation plan (and program) has been completed and was officially approved by the necessary state and federal agencies last fall. It reflected a state interagency participation of substantial importance and also significant multicounty regional contributions. Coordination with appropriate federal agencies was continuous and during the several years involved (1965-1971) fairly typical with regard to the tensions of bureaucracy balanced with moments of understanding.

Building on this experience and the growing recognition for state planning, both functional and comprehensive, in Pennsylvania, the staff directed attention in 1970 to a program design for state comprehensive development planning. That effort dealt with state responsibilities in terms of goals, objectives, and targets; considered social, economic, and physical concerns; took into account a regional view in formulating judgments "from Harrisburg," as it were; and looked at each major responsibility within the spectrum of the others in the interest of gaining a more viable sense of the costs and the benefits of alternatives.

With the emphasis now being placed by the Governor on a state investment plan, the economic focus has taken on heightened priority, a judgment appropriate to the times. The Office of State Planning and Development (formerly the staff of the State Planning Board) has been established, directly responsible to the Governor, and is charged with the responsibility to prepare that state investment plan within 16 months (starting January 1972). It remains to be seen how time and circumstances will permit comprehensiveness to be dealt with in the development of the state investment plan. It is expected that the state investment plan will provide the framework for all functional plans and planning, including (and especially) transportation.

It is not clear, however, how it will deal with the growth versus no-growth issue that considers not only economic productivity but social and environmental impacts as well, a value structure that Toffler talks about in Future Shock, or the contrasting views of an affluent society versus one that is going through the dislocations of a recession and 6 percent unemployment.

The times and the state of the art suggest that state development policies and planning be approached incrementally with regard to both time and major elements. It should deal with time in the sense of building on an issues-oriented base, which covers major questions a state government may face and increasingly rounds out the comprehensive context within which information is compiled, analyses are made, and judgments are formulated. It should deal with major elements in the sense of formulating a policy posture in major areas of responsibility, on a functional basis, drawing from increasingly shared population, economic, and land use (for example) information and analyses.

State development policies and planning, including transportation, need to reflect a common base of population, economic, and resource information and analyses. State governments need to be encouraged to move more in the direction of a goals definition that is part of a systematic consideration of overall objectives, targets, needs, deficiencies, implementing programs and projects, and the periodic recycling of these judgments.

Functional elements will always compete for priority of attention and support, e.g., transportation versus education and welfare versus environment. But if each functional element is to be viewed and understood as fitting into a total structure rather than as being the umbrella for the solution to all questions, then overall definition and direction must gain the same recognition and support and produce a usefulness that often is associated only with the reality of a physical facility we can see and use.

This larger context is important for transportation decisions. It is essential to intermodal judgments. This larger context is important and is essential to transportation decisions and intermodal judgments, among other reasons, because these decisions and judgments should be used by society in shaping what it determines it wishes to be.

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STATEWIDE INTERMODAL TRANSPORTATION PLANNING IN THE LESS URBANIZED STATE

William H. Wilson, Research and Planning Bureau, Tennessee Department of Highways

• THE 1970 census indicates that 58.8 percent of Tennessee's population resides in urban areas. There are 18 of the state's 95 counties that have an urban population exceeding 50 percent of the total population within these counties. Four urbanized areas in these 18 counties account for 1,488,624 persons or 64.6 percent of the total urban population in the state. Total land area in the state is 41,328 square miles, and the 4 counties containing urbanized areas account for 2,321 square miles or 5.6 percent of the state's land area. Population density in Tennessee ranges from a high of 956.3 persons per square mile in Shelby County to a low of 12.7 persons per square mile in Perry County; the state's average density is 94.9 persons per square mile. Population densities in the 4 urbanized areas range from a high of 3,584 to a low of 1,187 persons per square mile. From the foregoing, it is evident that Tennessee does not compare, in degree of urbanization, with the northeast corridor or major population centers of the United States.

Transportation available in Tennessee includes highway, air, rail, waterway, and pipeline. Total highway mileage amounts to 78,666 miles of which 9,488 miles are designated the Interstate and state system. Seventy-two percent of the state's Interstate System is open to traffic, and the remaining mileage is in the design or construction phase.

There are 9 commercial airports serving 13 air carriers in the state. During 1970 total aircraft operations at these 9 airports amounted to 995,840 flights. This number includes scheduled air carrier, charter, general, and military operations. Scheduled air carrier departures during the year totaled 127,586; 98 percent of the schedules were accomplished.

Currently there are 18 railroad companies operating more than 5,250 miles of trackage in the state.

Waterway operation is limited to the Cumberland, Tennessee, and Mississippi Rivers. There are 95 barge lines operating on the Cumberland and Tennessee Rivers. The Mississippi River being a major waterway provides a channel capable of accommodating numerous barge and ocean-going freighters. Freight shipments on the Cumberland during 1970 totaled 5.6 million tons; 597 million ton-miles were logged. Freight shipments on the Tennessee totaled 25.5 million tons, and 3.668 billion ton-miles were logged. Complete records for freight shipments on the Mississippi were not readily available, but the Port of Memphis handled 8.1 million tons during the year.

Seventeen pipeline companies operate 4,660 miles of pipeline traversing and terminating in Tennessee.

Intermodal transportation planning efforts have been, in years past, definitely limited on a statewide basis. During the past decade when a major emphasis was placed on the comprehensive, cooperative, and continuing urban transportation planning process, as required by the Federal-Aid Highway Act of 1962, intermodal planning has been recognized as a necessity. Therefore, impetus was given to incorporating planning for all modes into the process.

Historically, the Department of Highways has been responsible for all highway planning and urban transportation studies. The department's experience in origin-destination surveys dates back to the early 1940's when studies were concerned primarily with specific route locations rather than with the development of an integrated street and transportation system. The Nashville Urban Area Transportation Study was initiated in 1958 and was the first comprehensive study undertaken in the state. This

study was a cooperative effort, and the Department of Highways was responsible for the travel and terminal facilities inventories, analyses, and report publication. An agreement with the local governing bodies assigned responsibility for all related studies to local government. All subsequent urban study agreements have assigned related study responsibility to local government.

These agreements have stipulated that there would be a study of air, rail, water, and transit coordinated with the highway and street planning study. Through the cooperative process, total transportation deficiencies have been identified, and recommendations to alleviate deficiencies by improving access, terminal facility location, joint use, and exclusive transit use resulted.

A specific example of coordinated intermodal or multimodal planning resulted in the recommended sharing of a high-use corridor in Memphis. Here an existing railroad right-of-way and trackage in the median of a proposed freeway could serve existing high-density residential development, Memphis State University, existing rail and trucking terminals, and proposed high-density residential and commercial development. This corridor development concept also provides for an interchange with a proposed freeway extension to serve future expansion of Memphis International Airport.

The modal-split analysis and transit-use projections in the Memphis studies did not indicate that rail rapid transit would be feasible during the current planning period, but the corridor design concept does not preclude rail rapid transit with terminal parking at some time beyond 1985. The present railway intersects with another railway that traverses the central business district and serves a highly developed industrial area along the Mississippi and Wolf Rivers and the Wolf River Harbor. This corridor, when developed, will provide, through early and continued planning during implementation, expeditious travel among terminal facilities serving all modes present and anticipated in Memphis.

Another example of intermodal planning in urbanized areas resulted from TOPICS planning that has currently advanced to the implementation stage. In Nashville, detailed analysis of transit operations along 1 route was included in the TOPICS study, and high transit usage locations were identified. These locations were selected for special design consideration; and special bus pullout lanes, lighted and heated shelters, and adequate signing are being designed. The selected sites are so located that the buses can exit the pullout lanes during the main street red phase of traffic signalization, and consideration is being given to include detection in the pullout so that preemption by the bus will minimize stop time at the special shelters. Special agreements with shopping centers having surplus parking facilities are being negotiated in an attempt to generate park-and-ride usage along this route. If these concepts and designs prove successful, they will be followed in all high-use corridors in the area. Similar concepts are being utilized in Chattanooga and Knoxville.

Currently the Department of Highways and the City of Knoxville have an agreement to share financially in the development of an expressway facility in Knoxville that would provide improved access between a major pipeline terminal and the Interstate System. This terminal is the distribution point for much of the fuel used in portions of states.

During the intermodal planning relating to the location of the Interstate System in Tennessee, airport access was considered from the beginning. During the preliminary location and subsequent cost estimate studies, origin-destination survey data from earlier studies were used and supplemented with current traffic volumes to the 6 major air carrier airports in the state. Available data provided the necessary inputs to ensure adequate access to the larger airports in the state. Subsequent studies and coordination with the airports have resulted in planned or constructed freeway or expressway access to 4 of the state's airports. Present planning and coordination with the Knoxville airport will result in improved access to a new terminal facility currently under construction. Coordination with the Tri-Cities Airport Authority has guided construction of airport access and parking facilities at the terminal and established design of an expressway connection between the terminal and Interstate 81. This airport and Interstate route serves the highly industrialized areas of Bristol, Kingsport, and Johnson City in east Tennessee.

Permanent automatic traffic recorders have been installed at the main entrance to Tennessee's 2 largest airports. Annual traffic counts are made at all other air carrier airports. Data from these traffic recorders provide sufficient surveillance to monitor ground transportation needs. Periodic travel time studies between the central business district and each airport are conducted to monitor access traffic operational characteristics. These data have been and are being used to recommend TOPICS improvements where traffic congestion problems have been identified. Airport managers, authorities, or commissions provide the Department of Highways with statistics on enplaning and deplaning passengers, airfreight and airmail shipments, and number of charter flights on an annual or as-requested basis; and these data are correlated with the traffic data to establish trip generation rates to be used in planning studies. Additional air travel data will be available for coordinated planning studies on completion of a statewide air travel sruvey. Urban and statewide study inputs have been provided by the Department of Highways.

Completion of statewide transportation planning studies has been slow because of involvement in the nationwide Highway Functional Classification and Needs Study and other studies that are assigned a higher priority. The Research and Planning Bureau agreed to undertake a statewide O-D model development study several years ago, and considerable effort has been expended. Our concept in this study has been to treat the state as a large urban area and develop trip generation and distribution models. It was agreed that the state boundary would form the external cordon, and O-D stations were selected at all major local, state, and U. S. route crossings of the boundary. Current urban area external O-D stations in 5 state-line urban areas were recoded and incorporated into the data base. The Kentucky State Highway Department subsequently initiated a similar study and agreed to cooperate by conducting the state-line interviews at half of the O-D stations along the Kentucky-Tennessee boundary. The total number of external O-D stations being used in the study is 91. Internal traffic zones for the study were established by utilizing U. S. Bureau of the Census standard location areas, or aggregates thereof, which are basically census county divisions. The total number of zones being utilized is 535.

Internal (home) interviews were conducted after standard location areas were stratified by population density, and cluster samples were selected in 120 areas. The standard urban area home interview form was used in obtaining internal travel patterns. These data have been supplemented with small urban area O-D data recoded to the appropriate format. All small urban area O-D studies initiated subsequent to the statewide O-D model development study have been coded to the statewide format and incorporated into the base file.

The Research and Planning Bureau in cooperation with the Parks Division of the Department of Conservation conducted origin-destination surveys at all state parks in an attempt to identify vacation and recreational travel within the state. These data are obtained during peak vacation and recreation travel periods that include holidays and weekends. These data have been used to coordinate development of improved access to state parks and will be incorporated into the statewide model development study.

An inventory of commercial vehicle travel patterns was obtained concurrently with the home interview phase of the study. The Tennessee Motor Transport Association provided a listing of all trucking firms operating within the state, and the interview sample was selected from this listing. The sample was controlled to include over-the-road, transfer, and local delivery operations. These data supplement external O-D truck interviews and have been further supplemented by annual loadometer studies conducted in the state.

Analysis to date includes building the statewide network, plotting selected trees, and assigning present external traffic to the network. Preliminary trip generation analyses have been initiated but will not be completed until additional census data are available and statewide employment data recently ordered are received.

The Department of Highways has recognized the need for expediting completion of the statewide model development study. A consultant has prepared a proposal to develop and document a study design and evaluate data input requirements. It is anticipated

that the consultant contract will also include completion of the study analysis and document coordination of planning evaluation techniques to be used in the state's long-range priority programming procedure.

Intermodal planning gained emphasis at the state highway department level during completion of the National Highway Functional Classification and Needs Study (1970-1990); the department was designated coordinating agency for the National Transportation Planning Study. The Research and Planning Bureau was designated to provide required input from the highway study and assist the Highway Programming Bureau with coordination for other modal inputs. A consultant was employed to assemble all inputs and prepare the required data submission and narrative. Scheduling required considerable cooperation among the consultant, Highway Programming Bureau, Research and Planning Bureau, Tennessee Aeronautics Commission, development districts, councils of government, and local planning commissions. Data relative to air and transit usage and needs available from the urban transportation planning process were provided to the department's consultant. Subsequent evaluation of the data resulted in departmental and consultant contact with the above-indicated agencies to secure additional data where needed. During the final analyses, each airport agency, transit operator, and local planning agency was invited to evaluate the results of the various funding level allocations, and final needs adjustments were made.

Future intermodal transportation planning in Tennessee will be enhanced as the long-range priorities programming techniques are evaluated and modified and a statewide data bank is developed. The data bank will include but not be limited to a complete inventory of the highway system stratified by the state's functional classification, geometrics, structural condition, traffic volume, accident record, improvement cost estimate, and priority for improvement. A supplement in the data bank will include land use socioeconomic inputs to assist in an annual systems evaluation and intermodal planning coordination. It is anticipated that the Department of Highways will be reorganized and that a department of transportation will be established during the current year. Operations within the framework of the proposed department of transportation will strengthen our existing excellent working relation with all transportation modes, and intermodal planning will continue on a more meaningful base with divisional responsibility for the various modes being aligned under one administrative officer.

STATEWIDE COMPREHENSIVE TRANSPORTATION PLANNING

Lester A. Hoel, Transportation Research Institute, Carnegie-Mellon University; and
Owen H. Sauerlender, Transportation and Traffic Safety Center,
Pennsylvania State University

•IN 1967 the Governor of Pennsylvania established a Committee for Transportation and charged it with the responsibility of developing a master plan for transportation and preparing an organizational design for a department of transportation that would develop and implement the plan. The Governor's committee presented a design for a Pennsylvania Department of Transportation that was approved by the legislature effective July 1, 1970.

In addition to the organizational design for the department, the committee assisted by various consultants developed a series of related transportation studies and programs for action that could be used and implemented by the new department. These studies included an exhaustive annotated bibliography of material published on transportation in Pennsylvania as well as other relevant sources (1); an inventory of the existing transportation facilities in the state, the capacity of present facilities, and present traffic flows, based on all available information on highways, buses, trucking, railroads, pipeline, urban transportation, waterways, and air (2); a short-range analysis and forecast of intercity passenger and freight demand for the year 1975 based on extrapolation of existing trends and comparisons with present facility capabilities (3); an interim plan consisting of a listing of recommended projects together with a simple technique for evaluating project priorities (4); and a long-range program of comprehensive transportation planning at the state level (5).

This paper describes the elements in a program of statewide comprehensive transportation planning that was recommended for implementation by the department. The paper is in 2 parts. The first part describes the elements of the statewide comprehensive transportation planning process and the specific modeling tasks that were identified, and the second part describes the regional model for forecasting the flow of freight.

ELEMENTS OF STATEWIDE COMPREHENSIVE TRANSPORTATION PLANNING

The process of comprehensive transportation planning at the state level is not unlike the approach developed for urban and regional transportation studies. The planning process is intended to yield information necessary to select from alternative solutions those projects that will direct the state toward achieving regional goals. However, regional transportation systems have impacts on community development and differ in purpose from urban transportation systems. Transportation planning is an element of comprehensive planning at both the state and local levels, and the objectives of the master plan are both to serve movement between points and to reduce or where possible eliminate the need for movement. The statewide transportation plan is a guide to local area development and implementation and should include all modes of transportation. The plan should also be responsive to statewide programs for economic development and recreation.

The statewide comprehensive planning process consists of the identification of the appropriate policy and effect variables, the collection of data, the use of demand models, and the generation and evaluation of alternative systems.

Existing techniques for implementing and expanding these elements were reviewed, and the appropriate methods were selected with recommendations for additional research.

Identification of Policy and Effect Variables

The appropriate span of activity for a comprehensive statewide transportation planning effort is a logical starting point for developing detailed work projects and tasks. Ideally all variables should be included, but in practice the statewide transportation plan will consist of a network of links and nodes each described in terms of capacity, cost, and travel time. Although the statewide master plan is viewed as a corridor network based on relatively few traffic analysis zones, the interaction with local and regional analysis programs is an essential part of the planning program.

The process of transportation plan evaluation is still undergoing refinement and revision. Beginning with economic criteria as the sole measure of effectiveness, transportation plan evaluation has broadened to include cost-effectiveness measures and subjective rating methods that rank order attributes not measurable in economic terms. The evaluation process appropriate at the statewide level is a simple nonformal approach in which the relevant criteria are identified and modified through interaction with appropriate legislative, advisory, and technical committees.

Direct effects of transportation plans include travel cost and time, reliability, comfort, convenience, and safety. Indirect effects include measures of socioeconomic activity such as gross output, employment, population, and income. Both direct and indirect effects are essential information for decision-makers, legislators, lobbyists, and pressure groups whose interests must be understood and who must have the appropriate information on which to base decisions.

Data Collection

The infrastructure studies (2) gave substance to the expected conclusion that existing data are inadequate for implementing a comprehensive transportation planning effort. A key finding is the need for an extensive data collection program that would be used to fill gaps in existing information and to calibrate the forecasting models. The data needs are greatest for freight flows by all modes, passenger flows by bus and rail, and access flow patterns for all modes but highway. To achieve a goal of comprehensiveness in statewide planning requires that data be gathered for all modes and for freight and passenger movements so that the impacts on socioeconomic activity can be considered and travel patterns can be analyzed for the entire journey.

Demand Models to Forecast Statewide Travel

The demand models required to forecast future passenger and freight flows are the econometric model, the freight modal-split model, the passenger demand model, and the network simulation model. These four basic transportation planning tools represent the fundamental mathematical relations for predicting the future distribution and allocation of traffic flows among major nodes in the state. The relation among these models is shown in Figure 1.

The econometric model, to be described at greater length later in the paper, estimates the intensity and distribution of socioeconomic activity based on statewide population projections and the transportation network. The model, which is a form of "input-output," is based on the premise that industrial location and activity are primarily influenced by freight transportation. The output of the model is an origin-destination matrix for commodities and products between each industry.

The freight modal-split model is a multiple regression analysis that allocates the percentage of the total commodity flow between 2 zones to each mode on the basis of shipper characteristics such as reliability, cost, travel time, and frequency of service. The model selected is compatible with the output of the econometric model and consistent with the outputs of the passenger demand model. The "abstract mode" approach is reflected in the variables selected and will allow new modes to be considered, together with existing ones. Because of the relatively large average travel distance for commodities, a fewer number of zones should be required for freight-flow estimation than for passenger-flow estimation.

The passenger demand model is of the "abstract mode" class that uses a single equation to estimate the number of trips between each zone pair by mode. The recom-

mended passenger demand model includes the variables of population, institutional character, travel cost, travel time, number of modes available, frequency of service, and per capita income. An alternative approach that follows the usual trip generation, distribution, assignment, and modal-split procedure was not recommended because a simultaneous model that integrates the trip-making process is theoretically more sound and reduces the number of separate networks and iterations required.

The network assignment model follows conventional practice as developed in the manual published by the U. S. Bureau of Public Roads. The passenger and freight demand volumes by nonhighway modes are assignable directly. Vehicle conversions for passenger and freight flows are allocated to highway links by all-or-nothing assignments with capacity restraints.

Generating Alternative Transportation Systems and Evaluation

The transportation systems that will be developed as the basis for long-range implementation require that a series of plans be produced. The alternatives that are considered can be generated in a variety of ways but will rely on the interaction of the planning staff and the decision-maker. The state of the art of generating transportation supply alternatives is still reliant on judgment and experience. The existing network is a point of reference for modifications of the system, and changes will be based on estimates of travel demands, trip times, and cost that are produced by the demand model simulations. Techniques such as determining demand for travel on a specific mode, assuming that there is a ubiquitous network, can furnish insights concerning the most appropriate corridors and network configurations. The product of the iterative process of generation of alternatives, testing through demand simulations, and evaluation coupled with interaction between technical and policy staffs is a statewide master plan for transportation.

The planning methodology proposed for Pennsylvania was based on approaches that are consistent with contemporary transportation planning practice. The program was developed to permit early implementation of a statewide multimodal transportation plan. The models considered are those that both utilize proven planning practices and suggest new approaches that can be incorporated during the period that the master plan is being developed.

The recommended staging for implementing the program is based on 2 considerations: first, that the existing planning staff will continue and that maximum use should be made of this knowledge and experience and, second, that the creation of a master plan should not wait for new model development but should proceed on the basis of present operational methodologies. Accordingly, those elements concerned with travel demand forecasts and highway planning could be implemented prior to the development of the econometric model. In subsequent years the planning effort could be increased as data are made available.

The report envisioned 10 major tasks for implementing the program during a period of 60 months. The tasks that were included are review of methodological design; synthesis of existing data; design of data collection; collection of data; development of models including link grouping, network simulation, passenger demand, freight modal-split, and econometric; and integration of system.

The following section of the paper describes the econometric model that forms the basis for the socioeconomic inputs and forecasts of freight flow.

FREIGHT MODAL-SPLIT MODEL

The demand for transportation is a derived demand. The flow of commodities exists because production and consumption do not occur at the same time and place.

For any region the character of the commodity flows depends on the characteristics of the producers and consumers of the commodities and on their spatial distribution. Since every producer and consumer will require many commodities from various sources, the flow of these commodities becomes extremely complex, and any change in the socioeconomic character of the region will change the pattern of the flow.

The flow of commodities is accomplished by the transportation system that must be sufficiently versatile to provide the specific service requirements associated with the movement of any commodity. If all commodities were shipped in units of the same shape, size, and weight, there would be considerably less need for versatility in the transportation system. The growing importance of containerization results from the costs involved in maintaining a highly versatile transportation system.

The various modes of transportation employed in the complex movement of commodities are, perhaps, best differentiated in terms of their cost structures in relation to the spectrum of transportation services they provide. And since firms will tend to minimize their costs for any given service, the pattern of modal use throughout a region will tend to correspond to the pattern of commodity flows. In other words, the demand for various types of transportation services will depend on the specific mix of commodities for which the services are required. Thus, any attempt to forecast transportation needs for a region must be based on anticipated flows of different commodities throughout the region, but these flows are directly determined by the socio-economic structure of the region, that is, by the specific locations of firms that produce and consume goods and by the particular production process in which these firms are engaged. Thus, any serious attempt to forecast transportation needs of a region cannot take the pattern and operational distribution of economic activities as given but must provide a mechanism for anticipating redistributions that will result from changes in final demand and in cost structure, including changes in the transportation system itself. Gravity models, however sophisticated, all take as given the social, economic, and demographic pattern of the region. They have been very useful in short-term predictions of transportation needs, but they are totally inadequate for long-term forecasting.

The ideal transportation forecasting model for a region would present for any given point in time a table, or set of tables, that would show, at a glance, the forecast flow of traffic of each class and by each mode from every point of origin within the region to every destination. In addition, the table should show the extent to which each flow is impeded by the capacity of the transportation system. This ideal model might be difficult to develop, but it must be simple to interpret. In addition, its forecast should be highly reliable.

It was the purpose of the research team that worked on the "framework for transportation planning" to develop a transportation forecasting model for Pennsylvania that satisfied the criteria of the ideal model as defined above. It was recognized at the outset that a reliable model would require reliable data that were not currently available—good freight-movement data are almost nonexistent. Hence, the only data restriction imposed on the model was that it should not be unreasonable to expect that the required data could be collected. The model developed was based on the Leontief type of input-output technique but incorporates certain refinements that enable it to be responsive to changes in price, in freight rates, and in the transportation system itself.

Input-Output Model

The first step in the development of the transportation model is an input-output table that describes not only the shipment of commodities among industries but also their distribution throughout the region and the rest of the world. For this purpose it is necessary to identify shipments by commodity classification and by origin and destination. The table, then, consists of a column and a row assigned to each industry at every node (important center of economic activity) in the region, and additional columns and rows for nodes outside the region. The elements of a column are the flows of commodities from various sources to one industry at a given location. The elements of the corresponding row are the flow of goods from that industry to other industries throughout the state and to the rest of the world. The model requires that technological coefficients be computed for all inputs that are directly related to the various production processes.

Transportation services used by a firm are only incidental to the acquisition of resources and not directly involved in their productive use. There will, therefore, be

no rows assigned to this industry although there must be the appropriate columns. However, since the entire input-output table is a detailed description of commodity movements, it may also be regarded as an equally detailed description of the output of the transportation industry.

The fundamental unit in the model is the physical quantity of a commodity that is shipped from one place to another. Let X_{igjh} be the annual amount of commodity i produced in zone g that flows to industry j located in zone h. We assume that there is a one-to-one correspondence between commodity and industry. That is, commodity i is produced by industry i, where i may symbolize agriculture, steel, or glass. If there are n industries, then i and j will have values 1, . . ., n. Similarly, if there are m nodes, g and h will have values 1, . . ., m. The amount X_{igjh}, for the most part, will be given in physical units, e.g., tons, but in certain cases it will be expressed as dollar values.

For any given year (t), the complete set of all $X_{igjh}(t)$ for that year, written X(t), describes completely the flows of all commodities into and out of all nodes in the state. This set of $X_{igjh}(t)$ may be conveniently displayed in a table constructed in the manner shown in Figure 2.

Although the physical quantities of the commodity flows are the prime interest of the transportation model, it is necessary for certain computational purposes to have these flows expressed in dollar terms. Let p_{igjh} be the average price of X_{igjh} at the point of origin, and let f_{igjh} be the average cost per unit of shipping X_{igjh} from the point of origin to its destination. Then, $Y_{igjh} = (p_{igjh} + f_{igjh})\, X_{igjh}$ is the total delivered value of the amount of commodity i produced at node g and shipped to industry j at node h. (For purposes of the analysis, it will be convenient to proceed as though all shipment costs pass through the books of the firm at the origin of the shipment and are included specifically as shipment costs in the price paid by the purchasing firm. These assumptions do not affect the equilibrium solutions of the model but simplify the analysis.) For any given year (t), the complete set of all $Y_{igjh}(t)$, written as Y(t), describes the money flows corresponding to the commodity flows into and out of all nodes in the region. A complete table Y(t) may be constructed in a form similar to that shown in Figure 2.

Since we are particularly interested in the pattern of shipment costs involved in the movement of commodities, we define $S_{igjh} = f_{igjh}\, X_{igjh}(t)$. For any given year (t), the complete set of all shipment costs $S_{igjh}(t)$, written as S(t), describes the freight revenues corresponding to the freight movements throughout the system.

So that the Y(t) table might explicitly show all money flows within the system, it is necessary to add rows that account for strictly monetary transfers, such as taxes, interest payments, and undistributed profits, that are not directly related to the production processes. Various totals and subtotals are defined as follows:

$$X_{igjo} = \sum_{h=1}^{m} X_{igjh}$$

which is the total shipments of industry i at g to industry j everywhere. Totals of Y and S are defined in the same way as the total of X.

The next step in the development of the transportation forecasting model is the formulation of a methodology that will predict how the various inputs and outputs of industries throughout the state will vary with predicted changes in final demand, in cost structures, and in the transportation system itself. The theoretical basis for such a methodology is presented in the following 2 sections. When this methodology is implemented for some given future time period, the predicted commodity flows for that period would be presented in a table of identical form as that shown in Figure 2. For the reasons presented earlier, this table would be interpreted as a detailed description of the demand for transportation throughout the state.

The final stage in the development of the forecasting model is the assignment of the forecast freight flows to various modes and traffic routes. The method by which this is done was described in the first part of this paper. The detailed output of the integrated

set of models is a set of tables, each similar to the one shown in Figure 2 in that all commodity flows through the state are shown by origin and destination. In addition, however, the mode and the route used are also given. This degree of detail is necessary in the development of the forecast, but considerable aggregation is necessary for practical purposes. The final output is a table in which commodity flows are aggregated to show expected total freight movements by mode and route from origin to destination throughout the state. In the methodology by which assignment of commodity flows to specific modes and traffic routes is made, considerable attention is given to the capacity of the transportation system that is expected to exist in the period of the forecast. The final tables would, therefore, be constructed to show capacity utilization by mode and route in addition to the actual traffic flows.

From the foregoing description of the output of the forecasting models, it should be apparent that our criteria for an ideal transportation forecasting model would be met in that forecasts are to be presented in readily understood detail of the type necessary for comprehensive statewide transportation planning. It is necessary, however, that there should be considerable confidence in the reliability of the forecasts, and to ensure this requires that a sound theoretical framework be developed and that the model itself be implemented on the basis of adequate and reliable data.

The following 2 sections of this paper outline briefly the way in which a theoretical framework has been developed for making the technological coefficients of the input-output model sensitive to changes in costs of transportation.

Theoretical Framework of Input-Output Model

In the usual Leontief input-output models, the ratios

$$R_{igjh} = Y_{igjh}/Y_{oojh} \tag{1}$$

are formed. (The model usually omits specification of the originating mode g on the assumption that commodity i from all nodes is identical. The ratios then become Y_{ijh}/Y_{ojh}. The model here presented does not make the assumption given above for 2 main reasons. The first is that with the aggregation involved in any feasible commodity classification there will be considerable variation in the composition of shipments of the same class from firms at different nodes. The second reason for the specification of the point of origin is that this permits the development of a transportation sensitivity not possible without it.)

Each ratio R_{igjh}, so defined, is called a technological coefficient and is the proportion of total expenditure of firm j at node h that goes to purchase commodity i at node g. If these technological coefficients are assumed to be constant, the input-output model becomes consistent with the assumption that all industries have constant returns to scale. In addition, there is the implication that total expenditures for any commodity are insensitive to price changes. This, in turn, would be consistent with an assumption that industries operate like firms that minimize costs (or maximize profits) and have a very special form of linear homogeneous production functions—the Cobb-Douglas production function—which may be represented by the following equation:

$$X_{jh\infty} = \theta_{jh} \prod_{i=1}^{n} \prod_{g=1}^{m} X_{igjh}^{\alpha_{igjh}} \tag{2}$$

where the assumption is made that

$$\sum_{j=1}^{n} \sum_{h=1}^{m} \alpha_{igjh} = 1 \tag{3}$$

It can be shown that if these assumptions are made with the further assumption that total revenue equals total cost for each industry, then the technological coefficients of the Leontief input-output model at equilibrium are equal to the corresponding exponents of the Cobb-Douglas production function. Thus,

$$R_{igjh} = \alpha_{igjh} = (p_{igjh} + F_{igjh})\, X_{igjh}/Y_{oojh} \tag{4}$$

Figure 3 shows the solution for a 2-commodity model.

The curve Z represents the various combinations of x_1 and x_2 that yield the output Z according to the given production function. The curve Z′ represents a level of output higher than Z. The line joining c/p_1 and c/p_2 represents the combinations of x_1 and x_2 that can be purchased with a given budget C when prices are p_1 and p_2 respectively. (These p's are assumed to contain the freight rates.) The point B shows the optimum combination of x_1 and x_2 for a given budget C and indicates that Z is the highest level of output obtainable with this budget.

The ray OA is an expansion path. It gives the optimum combinations of x_1 and x_2 in the fixed proportion, $x_1/x_2 = (\alpha_1/\alpha_2)\,(p_2/p_1)$, that would be used for all levels of output with the prices held constant. If the price p_2 should fall to p_2', then the expansion path becomes OA′. The fall in price p_2 to p_2' leads to no change in the quantity x_1 if total expenditures for all resources (x_1 and x_2) remain fixed at C. It does, however, lead to an increase in the quantity of x_2 from $\alpha_2(c/p_2)$ to $\alpha_2(c/p_2')$ and to an increase in the physical volume of output from Z to Z′.

If, however, the output needed does not rise to Z′, then the quantity Z would be most efficiently produced with the combinations of x_1 and x_2 at the point B″ where the curve Z cuts the expansion path A′. At this point the ratios of the costs of the inputs remain as they were before, but actual costs of both inputs are cut by the same proportion. Thus, at whatever level of output the firm operates, the ratios of expenditures on the inputs are constant for efficient production. It may be shown that actual expenditures would be as follows:

$$p_1x_1 = \alpha_1\, C$$

$$p_2x_2 = \alpha_2\, C$$

That is, α_1 of the budget would be spent for x_1, and α_2 would be spent for x_2. These ratios are exponents of the respective x's in the production function, and, therefore, the production function can be derived from observation of actual expenditures for the different inputs.

The relations discussed above provide a means by which a production function can be used to provide a basis for the input-output model when the assumption cannot be made that all costs are for resources used in actual production.

The production function provides an equilibrium relation between total cost for productive resources and the level of output when the prices of resources are given. Thus, in the Cobb-Douglas 2-industry case presented above it can be shown that

$$C = (Y/p_y) \div \theta\, (\alpha_1/p_1)^{\alpha_1}\, (\alpha_2/p_2)^{\alpha_2} \tag{5}$$

or

$$Y = [p_y\, \theta\, (\alpha_1/p_1)^{\alpha_1}\, (\alpha_2/p_2)^{\alpha_2}]\; C = kC \tag{6}$$

If the technological coefficients are redefined as

$$R_{igjh} = Y_{igjh}/C_{jh} \tag{7}$$

where C_{jh} is the total cost of the resources that appear in the production function, then the input-output model in matrix form may be modified as follows:

$$RC + D = Y = kC \tag{8}$$

$$(k - R)C = D \tag{9}$$

where D is final demand and k is a diagonal matrix whose elements are the factors of proportionality such as that shown in Eq. 6 that relate the Y's to the respective C's.

Figure 1. Relation of demand models.

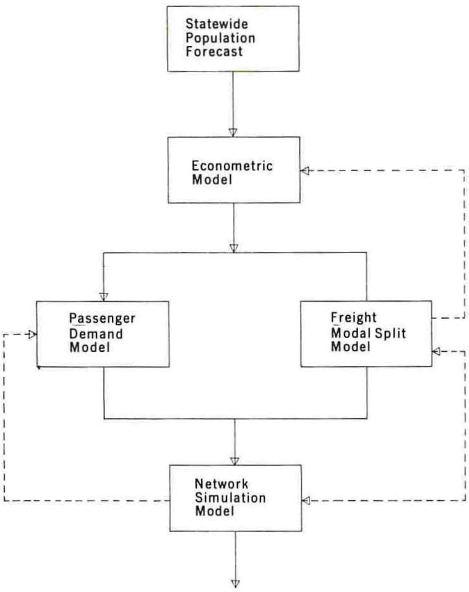

Figure 3. Determination of optimum input combinations.

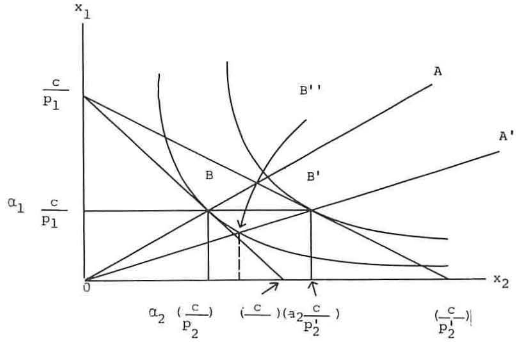

Figure 2. Interindustry internodal flows of commodities and services.

To / From	Industry 1 at Node		Industry j at Node	Industry n at Node		Total
	1	m	h	1 ...	m	
Industry 1 at node 1, 2, . . m						
S. Total						
Industry 2 at node 1, 2, . . m						
S. Total						
Industry i at node g			X_{igjh}			X_{igoo}
Industry n at node 1, 2, . . m						
S. Total						

The solution to the model given above becomes

$$C = (k - R)^{-1}D \tag{10}$$

on the assumption that the usual precautions are taken to ensure that R is square and nonsingular.

For a forecast D and for assumed prices and freight rates, the vector C may be computed from Eq. 10. It then is possible to construct from C and the set of technological coefficients a new input-output table that will show the flows of commodities resulting from the new D and the assumed prices and freight rates. It will also be possible to construct a revised table of all shipping costs. A comparison of this table with that for the base period will reveal the impact on the transportation industry of the changes incorporated in the forecast D and the assumed prices and freight rates.

Modification of the Model

It has been stated already that the usual input-output model assumes constant technological coefficients, that is, fixed proportions in the ratios of dollar expenditures for the different inputs of each industry. In the previous analysis it was shown how an underlying production function can be used to forecast changes in the proportions of physical quantities of inputs, and hence freight movement, that would result from changes in prices and changes in the cost of transportation. The price sensitivity introduced by this means might be adequate for practical purposes when inputs are aggregated and classified so that no commodity class is a good substitute for another. However, interindustry, interregional commodity movements typically show commodities of the same class but from different regions as inputs of the same industry. In such cases it seems reasonable to suppose that a change in the price differentials among competing sources of the same commodity class will result in more or less considerable change in the money flows as well as in the physical movement of these commodities. The input-output models so far developed have not been able to forecast such shifts. The following modification is sufficiently flexible to do this.

The variables in the model are defined as before. The proposed production function is given by the following formula:

$$X_{jhoo} = \theta_{jh} \prod_{i=1}^{n} \left[\sum_{g=1}^{m} (\alpha_{igjh} X_{igjh})^{\beta_{ijh}} \right]^{\gamma_{ijh}/\beta_{ijh}} \tag{11}$$

This formula is a combination of the Cobb-Douglas function given above and a "constant elasticity of substitution" production function. The Cobb-Douglas part of the function is seen in the following collapsed form:

$$X_{jh\infty} = \theta_{jh} \prod_{i=1}^{n} X_i^{\gamma_{ijh}} \tag{12}$$

where

$$X_j = \left[\sum_{g=1}^{m} (\alpha_{igjh} S_{igjh})^{\beta_{ijh}} \right]^{1/\beta_{ijh}} \tag{13}$$

The Cobb-Douglas feature of the function affords the limited price and transportation sensitivity previously discussed in connection with that function. But this limitation is confined to only the relations among the different classes of commodities. A considerably greater degree of price and transportation sensitivity is possible among the different sources within any given class of commodities. This additional sensitivity is derived from the constant, but unspecified, elasticity of substitution feature of the function, which is that part given by Eq. 13.

The total effect of the function given is to provide that any given industry will maintain the same ratios for expenditures among commodities of different classes but may

vary the shares of the expenditure on any given class that go to different sources. The precise nature of the shifts will become apparent from the following analysis.

It may be shown that if we assume that the sum of the γ's equals 1, then the proposed function is linear and homogeneous.

We now assume, as before, that each industry behaves as a single firm in combining its inputs so as to produce any level of output at minimum cost. The equilibrium solution for any industry is obtained by minimizing

$$C = \sum_{i=1}^{n} \sum_{g=1}^{m} p_{ig} X_{ig} \tag{14}$$

subject to the constraint of the production function

$$X = \left[\theta \prod_{i=1}^{n} \sum_{g=1}^{m} (\alpha_{ig} X_{ig})^{\beta_1}\right]^{\gamma_1/\beta_1} \tag{15}$$

where the subscripts j and h that identify the relevant industry and location have been dropped for simplicity, and p_{ig} includes the freight rate.

It may be shown that the equilibrium solution yields the following results:

$$\sum_{g=1}^{m} p_{ig} X_{ig} \div \sum_{i-1}^{n} \sum_{g=1}^{m} p_{ig} X_{ig} = \gamma_i \tag{16}$$

$$p_{iG} X_{iG} \div \sum_{g=1}^{m} p_{ig} X_{ig} = (\alpha_{iG}/p_{iG})^{\beta_1/(1-\beta_1)} \div \sum_{i=1}^{g} (\alpha_{ig}/p_{ig})^{\beta_1/(1-\beta_1)} \tag{17}$$

The relation in Eq. 16 states that at equilibrium the proportion of total expenditure that goes to commodity i from all nodes is constant and equal to the corresponding γ_i in the production function. This result is expected from the way in which a Cobb-Douglas feature is built into the production function.

The relation in Eq. 17 states that at equilibrium the proportion of expenditure for commodity i that will be spent at node G is a function of all the delivered prices of i from the various nodes. The parameters of the function are the corresponding α's and the β_i of the production function.

If Eq. 17 is modified by multiplying both sides by the corresponding sides of Eq. 16 we get

$$p_{iG} X_{iG} \div \sum_{i=1}^{n} \sum_{g=1}^{m} p_{ig} X_{ig} = \gamma_i\, (\alpha_{iG}/p_{iG})^{\beta_1/(1-\beta_1)} \div \sum_{g=1}^{m} (\alpha_{ig}/p_{ig})^{\beta_1/(1-\beta_1)} \tag{18}$$

The left side of this equation is the technological coefficient R_{ig} of the input-output table. We, therefore, have

$$R_{iG} = \gamma_i\, (\alpha_{iG}/p_{iG})^{\beta_1/(1-\beta_1)} \div \sum_{g=1}^{m} (\alpha_{ig}/p_{ig})^{\beta_1/(1-\beta_1)} \tag{19}$$

It is apparent that the R's are functions of prices and that they may be revised when prices change, provided that the coefficients of the production functions are known. Some progress has been made on the problem of estimating these functions, but more work is needed in this area (6).

It can be shown that the relation between y, the value of the product, and C, the total cost of productive resources, is given by

$$Y = p_y \theta \prod_{i=1}^{n} \left\{ \sum_k \gamma_i^{\beta_i} \alpha_{ik}^{\beta_i} \left[(1/p_{ik}) (\alpha_{ik}/p_{ik})^{\beta_i/(1-\beta_i)} \right. \right.$$

$$\left. \left. \div \sum_g (\alpha_{ig}/p_{ig})^{\beta_i/(1-\beta_i)} \right]^{\beta_i} \right\}^{\gamma_i/\beta_i} C \qquad (20)$$

$$Y = kC \qquad (21)$$

where k is the factor of proportionality in Eq. 20.

By means of the method presented at the end of the previous section, it is possible to adapt the technological coefficients given in Eq. 19 and the k's in Eq. 20 to a flexible input-output model that has considerable potential to reflect the effects of price changes and freight rates as well as changes in final demand.

The model presented in this paper was developed specifically for the analysis of the transportation sector; however, the methodology is readily adaptable to a much wider range of problems and offers much promise as an improved tool for planning.

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CURRENT STATE OF THE ART IN STATEWIDE TRANSPORTATION PLANNING

Roger L. Creighton and John R. Hamburg, Creighton, Hamburg, Incorporated

•THE subject of statewide transportation planning is one of intense interest at the present time. Thirteen states now have departments of transportation, and this number is expected to rise. The financial difficulties of railroads and some airlines are forcing states to consider what actions may be required in order to preserve those vital transport services. Citizens and political leaders, as well as professionals, want efficient and coordinated transportation systems so that tax dollars will produce the maximum in terms of transportation services for all people. And finally, there is a growing realization that the nation needs to consider alternatives to its present laissez-faire land development policy and that transportation is an important factor in land development.

The position of statewide transportation planning in 1972 has advanced to about the position of urban transportation planning in 1955. Fortunately, to improve this position, we have the advantage of knowing a great deal more about planning processes, goals, simulation, data collection, and evaluation. However, statewide comprehensive transportation planning is a larger and more complex subject than urban transportation planning. There are more modes. Both public and private organizations provide the services. And freight movement is a vital half of the problem.

Future advances in this subject area can be accelerated if we can reach a general agreement on what statewide comprehensive transportation planning should be, what its products are, what its methods are, and what the most acute problems are. It is as a contribution toward achieving this general agreement that this paper is directed.

This paper is based on work done by the authors on 3 concurrent projects. These include a project to develop a comprehensive statewide transportation planning program for the Pennsylvania Department of Transportation, the preparation of a chapter for the forthcoming 4th Edition of the Traffic Engineering Handbook of the Institute of Traffic Engineers, and the preparation of a position paper on the state of the art in statewide transportation planning undertaken for the Highway Research Board.

DEFINITION OF COMPREHENSIVE STATEWIDE TRANSPORTATION PLANNING

One of the first things that needs to be done in a consideration of comprehensive statewide transportation planning, either from the viewpoint of determining the state of the art or from the viewpoint of developing a new program, is to define what we mean by the term. The following definition is an example, prepared for and reviewed by the Pennsylvania Department of Transportation: Statewide transportation planning is defined as a series of activities that

1. Are undertaken to attain a series of goals or to improve performance in relation to a series of criteria;
2. Consider different groups such as people who travel, private firms that ship, private firms that sell transportation services, people who are in any way affected by facilities or services, and the general public;
3. Are involved in or involve recommending new or changed construction, operation, technology, price regulation, subsidy, and regulation of operations;
4. Consider modes of truck, rail freight, airfreight, waterways, ports, pipelines, air passenger and general aviation, bus passenger, rail passenger, and highway (automobile);

5. Involve planning by means of an orderly, objective process based on measurement but include inputs by duly elected officials and reviews by citizen groups and also include priority programming;
6. Are closely integrated and coordinated with land use, economic, environmental, and other plans;
7. Consider the entire state, including both urban and rural areas; and
8. Cover time periods ranging to 20 years.

Table 1 gives, for each mode of travel, the particular things that statewide transportation planning is concerned with and (for clarity) those things that it is not concerned with.

Each state will have a definition somewhat different from the foregoing, reflecting, among other factors, its geography, extent of urbanization, state governmental organization, and organization within a department of transportation.

PRODUCTS OF PLANNING

We can summarize the preceding definition by stating that, for most modes, statewide transportation planning is concerned with the following items:

1. Level of public investment;
2. Location (corridor locations for highway, bus, air, and rail and terminal locations for bus, air, rail, trucks, and waterways);
3. Type of facility within each mode (type of highway or type of airport);
4. Level of service to be provided;
5. Timing of investments and other actions;
6. Relation between transportation and (a) land use, (b) the economy, and (c) the environment; and
7. Cooperative, interagency decision-making (as an input as well as a means of effectuation).

The products of planning are recommendations regarding level of investment, location, type of facility, level of service, timing, and relation to certain external factors such as land use, the economy, and the environment.

Table 1. Subject matter of statewide transportation planning.

Mode	Is Concerned With	Is Not Directly Concerned With
Highway	System design in principle (mainly configuration, spacing, and geometric type) for all systems; corridor location for principal arterials; investment levels by type, location, and timing (both intraurban and statewide)	Route location; engineering design; corridors of secondary highways; traffic engineering and control
Bus (intercity)	Systems of routes (design and interline coordination); service levels (headways); generalized terminal location; pricing; bus size	Detailed terminal location; scheduling; internal management and operations
Air passenger and air freight	Systems of air routes and airports; generalized airport location, size, and investment; pricing; airspace use; utilization of airports by plane type and activity	Detailed airport location; scheduling; internal operations; safety; air traffic control
General aviation	Systems of airports; generalized airport location, size, and investment; airspace use; pricing; utilization of airports by plane type and activity	Detailed airport location; scheduling; internal operations; safety; air traffic control
Rail passenger	Rail passenger systems; generalized station locations; pricing; service levels (headways); investment; grade-crossing protection	Scheduling and operations; safety
Rail freight	Extent and design of system; investment; terminals, especially trailer- and container-on-flat-car (TOFC and COFC); system speed and pickup frequency; rail-truck coordination; pricing; grade-crossing protection	Scheduling and operations; safety
Truck	TOFC-COFC terminal locations; expressway location; truck size; safety; pricing	Operations; details of TOFC-COFC locations; safety
Waterway	Investment and maintenance costs; systems as related to rail and highways	Operations; recreational use
Port	Investment; coordination with rail and highway; interport coordination; generalized locations	Design, management, and operations
Pipeline	Impact on rail, waterways, and ports	Safety, management, and operations

TYPES OF PLANNING

How are recommendations developed? Planning recommendations are developed by demonstrating that the recommended actions will produce greater benefits or improved performance in terms of stated goals or standards than would be the case if other actions (or no actions) are taken.

Broadly speaking, there are 3 ways by which these demonstrations can be made.

1. A first-generation approach: the needs-standards approach—In this approach, standards are set for each of the separate modes of transportation. These may include standards of physical design (roadway geometrics), standards of service levels (capacity in relation to demand or frequency of public transportation service), and safety standards. The difference between the standards and existing (or future) conditions is the need. Generally, needs exceed financial resources, and therefore priority projects are identified, which become the program for construction.

The advantages of the needs-standards approach, which is basically the approach used in the 1970 National Transportation Planning Manuals of the U.S. Department of Transportation, are its simplicity, directness, and credibility and the fact that it can be done. The disadvantages of this approach lie in the fact that the standards tend to be mainly physical standards and the benefits to users and nonusers are not directly measured. As a result, comparisons of intermodal investment productivity cannot be made directly.

2. A second-generation approach: the single-mode simulation-evaluation approach—The single-mode simulation-evaluation process is derived from the urban transportation planning process. It typically contains 4 major elements plus the elements of data collection and programming implementation. The major elements are (a) the statement of goals or criteria, (b) the preparation of plans to improve performance in relation to those goals or criteria, (c) the simulation of present or future performance (or both) of the planned system, and (d) the evaluation of the results.

One basic distinction between the needs-standards approach and the simulation-evaluation approach lies in the nature of the goals. Standards tend to be physically dimensioned, relating to the facility itself, while the goals used in simulation-evaluation relate to performance as observed by people, whether as users or nonusers.

The advantages of the single-mode simulation-evaluation approach are that (a) it evaluates plans directly in terms of user and nonuser goals related to construction and operating costs, cost of travel, time, and safety; (b) it deals with and represents systems directly and thus leads to greater understanding; and (c) it offers the ability to add up costs (e.g., time) on the same basis for several modes and thus permits intermodal comparisons. The disadvantages of this approach are that (a) it is complex and difficult and (b) it is not currently operational for most statewide transportation systems—the exception being highway traffic simulation.

3. A third-generation approach: the multimode simulation-evaluation approach—In this approach, the demands for transportation, of both people and goods, are estimated for all parts of a state (13). The demands are then allocated among modes, and simulation is undertaken for all modes, much as in the single-mode process described above, except that allowance is made for feedbacks, as planned changes in service levels affect the choices of mode.

The advantages of this approach are that it deals with all modes of transportation simultaneously and presumably would permit more effective planning and coordination across all modes. The disadvantages of this method are (a) it is extremely complex, (b) necessary data are inadequate, (c) there is so little experience with this method, and (d) it is probable that the results would be quite generalized because the process is so comprehensive.

ASSESSMENT OF THE STATE OF THE ART

Given the preceding framework definition and categories of planning methods, we can make a quick assessment of the current state of the art in statewide transportation planning.

Our first observation is that all states, as required by the National Transportation Planning Manual, have completed, or shortly will complete, statewide transportation plans based on the needs-standards approach. These plans will cover, at least, Interstate highways, primary and secondary highways, urban extensions, TOPICS, urban public transit, general aviation airports, and air carrier airports. Most states will not have done any work in goods movement transportation (rail freight, canals, pipelines, or trucking) or in certain elements of long-distance person transportation (bus and high-speed rail). (An exception is the work done on the well-known Northeast Corridor Project.) Nevertheless, states will have done very substantial work at the first-generation level of planning. This provides a most important base that should be given recognition as a completed component of a statewide transportation plan.

In terms of second-generation planning, the record of accomplishment is by no means so extensive. The best record is in the highway field. Conversations with Philip Hazen of the Federal Highway Administration indicate that, as of mid-1971, 14 states have made some type of traffic assignment to statewide highway networks and 8 are in the process of developing or applying assignment techniques.

Probably the states that have gone the farthest in highway traffic assignment are Connecticut and Rhode Island. Connecticut has carried its assignment process through the testing of several alternative plans and has adopted a comprehensive statewide transportation plan with a tested highway element.

Conversations and correspondence with officials of many states indicate that the simulation-evaluation process has not been used at the state level in the planning of other systems of transportation. It is also clear that nothing has been accomplished yet in the way of third-generation, multimodal simulation and evaluation although at least 1 case has been reported in a foreign country (14).

FUTURE DIRECTIONS—A CASE STUDY VIEWPOINT

Given the current state of the art, the next question is, What should be the direction of future work in comprehensive statewide transportation planning? One way of getting a sense of direction is to interview state governmental officials not only in transportation agencies but also in planning and regulatory agencies. We did this in Pennsylvania and found that there was a surprising unanimity of viewpoint among officials despite their widely varying responsibilities.

The following concerns have been selected from a longer list of concerns expressed by Pennsylvania officials.

1. A strong need was felt for a systematic process for planning of rural highway systems.
2. Past transportation planning processes were criticized for slowness and, therefore, for the result that decisions were made in the absence of planning.
3. Costs of data acquisition are high, and obsolescence of data is rapid.
4. Pennsylvania officials felt very strongly that planning recommendations should be credible so that they would be accepted both within government and by the public at large.
5. Great concern was felt that the transportation improvements should play an effective part in promoting the economy of the state.
6. All officials interviewed, regardless of their responsibilities, felt that highway planning deserved the greatest amount of attention. Rail freight transportation and air passenger transportation vied for second place, some officials thinking one mode was in greater difficulty and some the other. (One official pointed out that all common carriers of passengers were in financial difficulty.) Planning for ports and for rail passenger transportation was felt to be somewhat less critical, although still important, while planning for pipelines, canals, and trucking received a low priority.
7. There was general agreement that a prime problem of planning is to develop a strong, mutually reinforcing relation between transportation plans and state land development plans. There was general agreement that transportation plans ought to serve land uses and encourage desirable patterns where possible; the need for a clear statement of state land development goals was urgently felt.

8. Since regulatory agencies must make their decisions based on today's problems rather than those of the future, a request was made to have long-range planners concern themselves with current fiscal problems of the private modes, as well as with long-range system plans.

The preceding represents a partial set of views of one particular state. Other states will have different emphases to give to statewide comprehensive transportation planning. But based on these and other conversations, there does exist a widespread interest in the subject of statewide transportation planning coupled with a desire for speed in planning and for relevancy in terms of the actions that state governments will have to make.

GENERAL RECOMMENDATIONS

It will be seen that there is a conflict between the desire on the part of top-level officials for plans to be ready quickly and the present state of the art in statewide transportation planning. A great deal of work needs to be done to bring statewide transportation planning to the level where it can in fact provide the kinds of outputs that are desired, and to do so with the speed that officials and public demand. For many modes, data are completely inadequate. Performance goals have not been clearly defined. Simulation and forecasting processes are not yet polished. A great deal of work must be done during the next few years. The following statements give the authors' recommendations regarding the key work items that should be undertaken.

Organizational Recommendations

Content—At the outset of its comprehensive transportation statewide planning program, each state should carefully define the contents of its own planning program, indicating the modes of transportation to be planned, the areas to be covered, the level of detail of resulting plans, and the basic techniques to be used.

Organization—A single organizational unit reporting as a staff agency directly to the head of the department of transportation should be created to handle planning for all modes of transportation in each state.

Coordination—Definite, regular lines of coordination should be established between the planning arm of the state department of transportation and other agencies, both public and private, whose work is closely related to transportation. It is extremely important that close technical working relations be established between state transportation planners and planners working for private carriers.

Process Recommendations

Performance Criteria—Early in the comprehensive statewide transportation planning program, agreement should be reached on standards and goals to be used in evaluating transportation systems. Most states are already estimating needs on the basis of standards such as those prescribed in the 1972 National Transportation Needs Studies Manuals. However, the use of goals that measure performance as observed by people—users, nonusers, and organizations—does not appear to have been accepted in statewide transportation planning. We recommend that statewide transportation planning move in the direction of establishing goals that directly measure performance of different types of transportation in relation to a broad set of user, community, supplier, and environmental goals.

Performance Measurement—It is recommended that statewide transportation planners start at once to measure the existing performance of transportation systems in terms of user, community, supplier, and environmental goals. This will require substantial data collection.

Data Collection—Extensive sets of data need to be collected for all types of person and freight movement among cities by all modes of transportation. Except for the highway mode, data are completely inadequate for performance evaluation, simulation, and general planning work.

Simulation Models—Simulation models should be improved for automobile and motor carrier systems, rail freight systems, and air carrier systems.

Land Development and Transportation—Better methods are needed for simulating the mutual impact of transportation facilities and land use.

Multimodal Evaluation Techniques—Improved methods are needed for more rational allocation of both public and private funds among the several transportation modes. These improved methods should be capable of dealing not only with construction, maintenance, right-of-way acquisition, and user costs but also with impacts of the transportation systems on land use, the environment, and the economy. Initially, statewide transportation planning will concentrate on single modes, but ultimately public and private investments must deal with all modes simultaneously.

Alternatives—The comprehensive statewide transportation planning process ought always to propose and test alternative plans rather than single plans.

Modal Priorities

Highway Planning—Highways, because they carry such high proportions of person and freight movements in all states, should continue to get the highest priority of planning attention but not at the expense of failure to plan for the other modes of freight and passenger transportation.

Rail Freight Research—There exists a great need for a study of the potential economies inherent in optimizing the extent and pattern of existing railroad trackage. There appears to be extensive duplication of trackage resulting from the existence of competing railroads. Many feeder tracks receive only marginal use. Planners should, at the minimum, determine the potential order of magnitude of savings resulting from the pooled use of rail trackage and from the planned coordination of rail and truck systems.

Air Passenger Study—A study of air passenger systems, without regard to airline ownership, should be undertaken at a state or preferably multistate level. Air passenger service should be viewed as a systems problem, including the ground journey at each end of the passenger movement, rather than simply as a one-airport-at-a-time problem.

Bus Passenger Study—Intercity buses carry an important proportion of all person-miles of intercity passenger travel and a large amount of the mileage where trips are less than 100 miles in length. The Interstate System has increased the speed of intercity passenger travel by bus. This mode of travel deserves planning attention.

CONCLUSION

Comprehensive transportation planning at the statewide level can become, in this decade, one of the most productive activities that state departments of transportation can undertake. Important decisions are being made in highway, air, rail, and other forms of transportation; these have a close tie-in with the economy, the environment, and land use. Better decisions can be made if more facts and better planning processes are employed. Greatly improved methods for data collection, planning, and simulation and evaluation have been developed since 1950 in urban transportation planning and in other fields. An intense effort is now needed to modify and expand these for use in statewide transportation planning.

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RELATION OF NATIONAL TRANSPORTATION PLANNING AND STATE TRANSPORTATION PLANNING

Arrigo Mongini, Office of Systems Analysis and Information,
U.S. Department of Transportation

•IN RECENT years, there have been new developments in both national and state transportation planning. In particular, at both levels of government, new emphasis has been placed on the ability to consider all modes of transportation, if not through the same analytical technique, then at least through the same planning process and the same organizations. The nature of the process has similarities and differences at the 2 levels of government. These will be discussed in this paper as will the new National Transportation Study, which has been designed to relate the state and national transportation planning processes more closely and more formally. There has been no attempt to trace the historical development of transportation planning at either the state or the national levels. The paper is just a brief statement of where things stand at present and where they are headed with some comments on where they should be headed. The reader is cautioned that the views expressed in this paper are those of the author and do not necessarily represent the policy of the U.S. Department of Transportation.

DEFINITIONS

In this paper, national transportation planning includes those activities that are aimed at helping the federal government to decide what actions it should take to bring about or otherwise encourage transportation operations and investments that make a maximal improvement to the national welfare. For a number of reasons, this type of planning does not typically involve the search for one or even several "optimal" configurations of transportation and certainly does not involve very much detailed specification of those configurations. In this paper, we will not dwell on defining the national welfare. State transportation planning has more or less the same purpose, except that instead of the national welfare state planning tries to enlighten the decision-making process for improving the welfare of people or organizations that operate within state boundaries. Generally at some point in the planning process, it involves specifying in detail the nature of facilities to be built.

SIMILARITIES AND DIFFERENCES

Before we consider the ways in which these 2 activities can complement each other, it is interesting to reflect on how they are similar, how they differ, and why.

Reporting

Both processes require reports at regular periodic intervals not only for use in the executive branch of the government but also for use in developing legislative guidelines. Such reports are also necessary for the purpose of publicizing the recommendations in order to obtain the public's reaction and criticism. This is especially important in the legislative process, where considerable debate may take place and changes get made before the final provision is enacted. The reports in effect become reference documents and basic starting points leading to an eventual refinement of the proposals.

Continuing Nature

Besides the continuity of the regular reporting cycle, the planners at both levels of government must be prepared to respond at irregular times during the cycle. Proposals are made very often from outside the regular administrative channels, for example, by community organizations or individual legislators at the state level or by special interest groups at the federal level. These proposals must be evaluated and compared with those that are currently favored by the administration. Ideally this evaluation should take place in the same organizational framework as the one used to develop the administration proposal or official plan.

Time Horizons

Both processes involve long-range planning and short-range programming and budgeting. Perhaps one of the major shortcomings of both processes is that in most cases the long-range planning work and the programming are done by separate groups and are generally not coordinated. It is interesting moreover that, at least until recently, most of the planning energy at the federal level has been focused on the programming and budgeting process (essentially a short-range one), while at the state level and especially at the urban level emphasis has been placed on long-range planning and the technical description and evaluation of systems that should or would exist about 20 years in the future.

Hierarchical Structure

The national transportation planning process embodies, at least in theory, one additional degree of hierarchical complexity beyond that of the state process. The state process must consider the plans and programs of metropolitan-wide organizations as well as those of individual local city and county governments. The national process theoretically involves another level of hierarchy—that of the state. In practice, however, the complexity at the national level is somewhat lower because of the differing responsibilities of program and project control vis-à-vis the next level of government down. The state in most cases will actually build and operate transportation facilities (highways in particular) within the boundaries of its local governments or metropolitan planning bodies. In the case of the federal government, this is generally not true with respect to the state except for navigable waterway investments and the airway system. Thus, there is less activity devoted to coordinating transportation programs of direct investment or operations with those of the next lower governmental entity simply because there are very few projects of direct federal investment.

Relation to Other Government Activities

At both levels of government, transportation planning is expected to be in step with other government policies and plans in areas such as land use planning, regional economic development policy, and pollution control.

Private Sector Participation

The nature of private sector participation in the 2 processes reflects the differences in scale and organizational responsibility. At the state or local level, the activities and location plans of individual plants are of great interest to transportation planners as are the specific operations of individual carriers. At the federal level, transportation planners are interested in the industry's projection of new technology and its effects and the industry's views regarding investment plans, particularly for vehicles that might operate on routeways provided at public expense. Beyond this, large portions of the system are provided and operated entirely in the private sector, including pipelines and railroads. In these cases the federal government is interested in industry plans for investment or disinvestment in fixed facilities in a nationwide sense, while individual states are understandably more concerned about individual service abandonments within their boundaries and their impacts on usage of other facilities.

Technical Methodologies

The states have been adapting some of the techniques of network analysis originally developed for use in the urban transportation planning process. At the same time, the federal government has developed nationwide networks similarly adapted for use in examining national passenger and freight issues; however, the application of these techniques seems to be more advanced at the state level. One problem of network analysis at the national level is the fact that travel on the highway system is predominantly local with respect to the national scale and is not easily represented on a coarse-grained network such as that required for computational feasibility in national models. This, of course, is less of a problem in statewide networks where one can usually afford a finer zone and link structure.

At the federal level, the Department of Transportation has become interested recently in models that express transportation supply and demand in aggregate, non-network, terms. These simpler relations enable very rapid calculations to be made regarding numerous system alternatives for numerous different geographic areas (such as urban areas). At the same time the need for such techniques at the state level and even the urban area level is being recognized for much the same reason. Despite the advances in computational speed and unit cost, the network analysis methods are still quite time-consuming for use in testing a multitude of alternatives; thus, the relative desirability of the aggregate techniques is increased.

Types of Analysis

Individual project analysis is less important at the federal level because most projects are not built directly by the federal government but are sponsored by states and local governments with federal aid. Moreover, the Department of Transportation Act, at least by one interpretation, appears to limit the authority of the executive branch of the federal government to even set criteria for performing investment analysis. In contrast, the states are, or at least should be, concerned about matters such as the analysis of alternative highway or public transportation route locations or decisions about whether one project should receive priority over others.

One type of analysis of special interest at the federal level but less at the state level is analysis in support of a decision to develop specific vehicles and their associated system components. Examples are the SST, high-speed rail technologies, vertical and short takeoff and landing aircraft systems, and components of the aviation system. Sometimes, individual project analyses are needed in support of these issues as concrete examples of where the vehicles might find use.

Also in a similar position with respect to state or federal interest are questions related to specific policies, such as increases in user taxes, economic regulation, safety regulation, and so forth, although there would appear to be more grounds for state interest here than in questions of vehicle development.

Analysis of the optimal extent of a system or of service offered appears to be of great interest at both levels of government since it has implications regarding future appropriation of funds. This common area of interest has become a focus of cooperative planning between federal and state governments, whether through "needs" studies or through the new National Transportation Studies, and will be discussed later.

Multilateral Viewpoints

In addition to the viewpoints of the various governmental entities, both levels of government must also take into account the views of and impacts on other identifiable groups within the population, such as poor people, local businesses, and citizen groups. Analysts at the national level are often called on to evaluate the impact of policy or program changes with respect to specific interest groups or geographic regions.

Evaluation of Progress With Regard to Objectives

An important part of the planning process at both state and federal levels is the identification of goals and objectives of public policy and programs, possibly in quanti-

tative fashion. As an adjunct to this, it becomes important to trace the actual performance of the transportation system through time with respect to the announced objectives and to forecast the anticipated performance in the future if alternative policies and programs were implemented. For this purpose, a set of indicators of system performance must be developed to make such evaluations.

This type of evaluation is an extremely valuable tool of public policy in a democratic society. The layman and the political decision-maker often have difficulty in accepting benefit-cost analysis when many intangible or incommensurable measures are involved, especially when programs in transportation are evaluated against programs in other areas such as health services. Moreover, attempts to establish investment "needs" based on specific idealized standards simply beg the question of the impact of alternative levels of expenditure and are somewhat difficult for the public to conceptualize and to compare with investment needs in other areas. At least the public has some feel for the current level of transportation service (or health service), so that attempts to express changes in performance with respect to current performance and to relate these changes to levels of expenditure are probably more useful for public policy making than benefit-cost or needs techniques at both federal and state levels of government.

MUTUAL SUPPORT OF STATE AND FEDERAL TRANSPORTATION PLANNING EFFORTS

The foregoing discussion has pointed out a number of similarities and differences between the planning activities that appropriately take place at the state and the national levels and has shown how these relate to the respective functions of the state and the federal governments. This leads to the following conclusions regarding the ways in which the activities at each of the 2 levels of government can support the other.

Timing and Continuity

Under an ideal system the reporting dates and the frequency of reporting plan and program information should be the same for all states. The corresponding federal reporting frequency or frequencies should be the same as those for the states but possibly offset by a year to allow feedback between the federal and state results. Such a system, however, would neglect possible inefficiencies of manpower utilization since consultants, who are experts in a particular phase (e.g., data collection), may therefore not work in several states in sequence because the same type of activity would be going on in all states at once. Of course, because of the individual requirements of each state as determined by state laws, some of the state reporting dates might have to be out of phase with the federal requirements, in which case methods of making small adjustments for federal reporting purposes should be devised.

Time Horizons

The ideal system for federal purposes would be to maintain the same time horizons for plans and programs at any given point in time. This may also require adjustments to be made for federal-state compatibility.

Use of State Planning Data at the National Level

The federal data and analysis program should be geared to rely on the data bases generated as by-products of the state planning process as well as certain secondary sources outside the scope of the state.

Exchange of Talent

Professional planners at either level of government should be encouraged to spend some time at the other level in order to promote exchange of ideas.

Private Sector Coordination

National trade associations should be encouraged by the federal government to request that their membership in specific states or regions work with state planners in coordinating development strategies.

Performance Measures

A comparable set of performance measures should be promoted for use by the various states, against which progress through time and among areas may be compared. This is in contrast to a system where specific planning standards of performance are specified. The latter system reduces the scope of the state to selectively emphasize its own goals and objectives.

Evaluation Techniques

The use of comparable system evaluation techniques and associated methodologies should be promoted for use among the states.

Planning Assistance

Since much of the responsibility for system planning rests with the state, the federal government should seek to increase the state's capabilities in planning and programming and thereby increase the rationality with which the national system is planned.

Compatible Planning Assumptions

In addition to providing financial aid for state planning purposes, the federal government should provide information with respect to travel and freight projections as well as cost-estimating guidance and assumptions with regard to the availability and physical characteristics of new technological systems. This not only increases the comparability of the state plans and programs for federal purposes but also makes available valuable information for the state planning process.

Methodological Research

Because of the similarities in technique in state and national planning, efforts to improve the state of the art in different areas would have payoffs at both levels.

Wide Publication of Performance Measures

The public at large, the political decision-makers, and the planners themselves would benefit from having wide dissemination of indicators of current and anticipated performance of the transportation system such as overall speed, accessibility, and transit coverage.

THE NATIONAL TRANSPORTATION STUDY

After the initial experience with the first National Transportation Study (NTS), the new system is somewhat a refinement and will reflect a long-term effort to relate more closely in a technical, an administrative, and a political sense the state and federal transportations planning processes.

The following objectives have been established for the NTS:

1. Quantify the Nation's existing transportation system and future planned transportation system in terms of a set of consistent nationwide measures;
2. Provide the Secretary of Transportation and the Congress with information on which to base future national transportation system programs and policies;
3. Aid in evaluating the performance of the Nation's existing transportations system in terms of its contribution to national, state, local, and private sector goals according to a set of desired criteria;

4. Aid in identifying the deficiencies in the existing transportation system with respect to national, state, local, and private sector goals;

5. Aid in developing appropriate recommendations regarding federal-aid program authorization levels and structure to facilitate the implementation of recommended plans and expenditure programs;

6. Evaluate alternate future transportation systems in terms of performance measures at the national level and encourage similar evaluations at the state and local levels; and

7. Contribute to the improvement of the overall transportation planning process by encouraging at all levels of government (a) the continuing coordination of the U.S. Department of Transportation planning grants to facilitate comprehensive multimodal planning, (b) the development of comprehensive transportation plans reflecting state and local goals for both the long range (15 to 20 years) and the intermediate range (5 to 10 years), (c) the development of intermediate-range expenditure programs incorporating the higher priority elements of these plans, and (d) the development of a systematic data management system for continuing reporting of information regarding transportation system performance.

This study is to encompass planning with regard to all major modes of transportation, and the process is designed to make maximum use of the information developed through existing planning assistance programs of the department in highway, airport, and public transportation modes and information developed by public and private agencies with regard to other modes of transportation.

The NTS encouraged multimodal planning activity and the coordination with comprehensive planning that includes economic development, land use, and provision of other public services. Both long-range plans (1990 for the 1974 study) and short-range programs (to 1980) are to be reported by the states. In addition, a report on the 1980 plan is requested in order to compare the implications of the long-range plan with the program for a common year. The program would be developed with particular attention to budget constraints and sources of funds, including estimates of federal-aid funds available to each state during the period 1972 through 1979. The plan would not require strict consideration of budget constraints. In addition, information with respect to a base-year (1972) inventory is required.

The following comprehensive set of information will be reported:

1. 1972 inventory—physical state of the transportation system existing as of January 1, 1972, low-capital and noncapital programs existing as of January 1, 1972, transportation system operating costs for the year 1971, and performance of the transportation system existing as of January 1, 1972;

2. 1990 plan—description (in terms used for 1972 physical state) of the 1990 transportation system plan resulting from the transportation planning process, performance of the 1990 transportation system plan, description of low-capital and noncapital programs that are part of the 1990 plan, operating costs in constant 1971 dollars for the year 1989, and costs to develop the 1990 planned system (1972 to 1990) in constant 1971 dollars;

3. 1980 plan—description of the 1980 transportation system plan resulting from the transportation planning process, performance of the 1980 transportation system plan, operating costs for the year 1979 in constant 1971 dollars, description of low-capital and noncapital programs that are part of the 1980 plan, and costs to develop the 1980 planned system (1972 to 1980) in constant 1971 dollars; and

4. 1980 program—description of the 1980 programmed transportation system, performance of the 1980 programmed transportation system, description of low-capital and noncapital elements that are part of the 1980 programmed system, costs to develop the 1980 programmed system (1972 to 1980) in constant 1971 dollars, operating costs for the year 1979 in constant 1971 dollars, and sources of funds (1972 to 1980) anticipated to finance the programmed system.

Emphasis is being placed on the use of transportation performance measures that describe the current system and future planned and programmed systems. These

measures describe not only the service that the systems offer or would offer to users but also some of the impacts on nonusers. Examples of performance relating to public transit service include percentage of population within walking distance of public transit service, average vehicle speed, average headways, and load factor. Examples of impacts on nonusers or the public at large include tons of pollutants by type and population within certain noise contours.

Beyond the information describing overall transportation systems in different areas, an additional less aggregative reporting is contemplated that would employ accessibility techniques to calculate the transportation service available to different population groups with regard to specific types of trips. Included here, for example, would be measures such as the percentage of area residents within specific travel times (by automobile and separately by public transit) to metropolitan facilities such as hospitals and schools. This type of analysis is contemplated only for urbanized areas of more than 500,000 population.

Besides their use at the state and urban area level, the following uses are contemplated for the information at the federal level.

1. Monitoring of system performance, physical development, and expenditures through time—Information regarding the 1972 inventory, future year inventories in future studies, and expenditure patterns between inventory years (beginning with the 1976 study) will be useful to the department in monitoring the effectiveness of transportation expenditures of different types through time. In a gross sense, this will indicate to what extent the system is improving, changing, or deteriorating, in what types of areas the effects are being felt; and in what way these phenomena relate to transportation expenditures, particularly federally aided ones. This would indicate whether program areas might warrant increased or decreased emphasis of the federal government.
2. Comparison among states and areas—The static information regarding the 1972 inventory will be useful in a comparison of the level of service offered, the physical facilities present, and their cost of operation among states and other areas. A time series of inventory information will eventually indicate those areas that make the most gains in different performance measures. Publication of these data will enable states to make comparisons of their own experience with that of other states in the context of the national system. In effect, this would begin to establish a minimum continuing transportation data base throughout the Nation. Analysis of this information would also indicate whether certain general types of geographic areas might warrant increased or decreased program emphasis by the federal government.
3. Comparison of long-range plans with current systems and comparison of long-range plan performance among areas—The 1972 inventory and the 1990 plan would be used to indicate the changes in system performance that could be anticipated if the plans were implemented and to indicate the cost. In a gross way, this would serve to point up what the Nation would be buying if the long-range plans were implemented in terms that can be related to current experience with system performance. The general public as well as public sector decision-makers would benefit from being able to relate anticipated changes to their current satisfaction or dissatisfaction with different elements of the system and to make judgments regarding the value of implementing such long-range plans at the estimated cost.
4. Comparison of current system with anticipated changes under current funding assumptions—The 1972 inventory and the 1980 program would be compared to indicate whether changes in funding at various levels of government and in different programs might be warranted. In effect, lack of progress in performance in certain program areas or geographic areas may indicate a need to shift funding priorities.
5. Anticipated progress in meeting goals of the long-range plans—The 1980 plan and the 1980 program would be compared in terms of the extent to which the anticipated budget-constrained program is on target with respect to attainment of 1990 plan objectives. This would be useful in setting realistic national objectives on which to base federal programs and policies.

6. Transportation expenditure priorities—The 1980 plan and the 1980 program would be compared in order to determine those programs to which states and local areas would assign higher priorities under funding constraints. This information, along with narrative information in the state reports, would indicate the extent to which state or local priorities are consistent with national goals and transportation policies, whether current programs and policies might impede progress toward certain state goals, or whether state and local programming decisions under current programs might produce deficiencies with respect to national goals.

7. Analysis of alternatives—The information will provide a cross section of various state and local government solutions regarding physical development, performance, and cost. This and secondary sources of data can be used to derive relations between the dimensions given above in such a way that one or more can be varied and the resultant changes calculated for the other variables. Some such analytical tools have already been developed by the department and are extremely useful in analyzing the sensitivity of system performance to alternative investment and operating policies. They are useful in answering questions such as, What would it take to make specific percentage improvements to optimize weighted service levels given budget constraints?

8. Sources of funds—The information regarding sources of funds for the 1980 program is considered necessary to develop realistic programs. The information can serve to identify at the national level the differences among the modes and geographic areas in raising operating and capital funds and in particular the extent to which expenses would have to be borne by the general taxpayer.

9. Consistency checks—Certain items of information are useful in checking the validity of the remaining items. For example, total operating expenditures minus operating subsidies divided by total passengers should be an approximate indicator of average fare on an urban public transportation system.

10. Status of plans—Information regarding the sources of information that was used in developing the plans and programs will indicate the extent to which department-sponsored plans and planning processes are kept current and are used in developing expenditure programs.

11. Exchange of information—Publication of all of the information given above will be useful in keeping states informed of progress in transportation performance throughout the country and will improve planning and programming practices by disseminating information on how the planning and programming process is carried out across the Nation.

12. Special issues—Certain of the detailed information will provide a basis for analysis of specific issues such as service to poor or elderly citizens and service to different land uses.

Of course, not all of the uses of the data given above will be fully developed after the 1974 study, but the intent is to develop reliable information for all of these purposes as time goes on and as the information system is improved.

Another important feature of the 1974 NTS is that the process is designed to encourage the involvement of elected officials in the planning and programming process. For example, the governor of each state appoints a representative to be in charge of the study and designates urban planning groups to coordinate the activity in each urbanized area. The urban planning group would ideally have a policy board including or responsive to local elected officials. In addition, states are encouraged to involve key legislative officials concerned with transportation, for example, by asking them to review the study results or to form an advisory board to oversee the study.

To summarize, the 1974 NTS and the continuing national transportation study have been designed in such a way that national, state, and urban transportation planning efforts may reinforce one another in a coordinated fashion.

NEW YORK STATEWIDE PLANNING PROGRAM: ACHIEVEMENTS AND PROSPECTS

Robert Breuer, Planning Division, New York State Department of Transportation

•IN LATE 1968, we released our first report, Policies and Plans for Transportation in New York State. We are now in the midst of a major update of our statewide transportation plan. It is now in draft form, and I hope it will be released early this year. I think one of the best ways of demonstrating what our experiences have been and what we have learned in the past 3 years is to compare this new report with the first plan report.

For one thing, documentation of the new plan will be longer; including its technical supplement, the new report will have, I expect, 4 to 5 times as many pages as the first report. (After 3 years of effort, one should hope so!) I mention this not just facetiously. The report will be longer because, where the first plan gave general guidelines, the new plan will make specific recommendations for state policies and actions. It differs in another way too: The new report focuses attention on new problems and on different aspects of old problems; these were only hinted at or not even raised in the first statewide plan. The new plan is concerned with the operation of the transportation system as much as with the extent and the location of facilities. It is concerned with the variety of ways government, and state government in particular, affects the provision and the operation of the system, not with just those elements for which the state has specific construction or operational responsibility. To make this clear, I want to review briefly some major elements of the second statewide plan—intercity passenger transportation by air, rail, and bus; rural highways; freight; and urban transportation—and highlight the differences between it and the first plan.

In the first statewide plan, we proposed a fourth airport for the New York metropolitan area and an airport in western New York State. Although we repeat those recommendations, after 3 years of fruitless effort toward providing new airports, our attention has turned increasingly toward improvements in the operation of present facilities. We must consider rationing the scarce capacity at existing airports, both as a short- and a long-term solution. The option of absorbing the increase in aviation demand through larger planes, and not through more frequent flights, must receive careful consideration. Such rationing would prevent the severe access, relocation, and environmental problems that would be caused by constructing new airports. This strategy would also reduce the serious noise problem at metropolitan airports, by encouraging the phasing in of the newer jets having quieter engines.

In the second statewide plan, we are more concerned with the level of air service to smaller cities, a subject that did not receive much attention in the first statewide plan. I expect that airlines will continue to acquire larger planes because of cost-cutting pressures as in the past and because of expected metropolitan congestion in the future. Regional airline service is diminishing or disappearing at many smaller cities because of inadequate demand or inadequate facilities for the larger planes. As alternatives to costly runway extensions or new regional airports, we are turning our attention to the commuter air carriers—the third-level airlines, which operate smaller planes. As a result, there are recommendations in the second statewide plan for changes in restrictive federal regulations on plane size and for operating subsidies as alternative investments of public resources.

We conducted a study of the applicability of high-speed rail service in upstate New York, following the recommendations of the first statewide plan. They study has led to detailed feasibility studies of a new service from New York City to Buffalo. However, the second statewide plan addresses the more pressing question of the required level

of conventional rail service and will contain recommendations for additional trains and routes to be added to the National Rail Passenger Corporation's basic system. Federal legislation permits such extension where a state will subsidize losses.

For rural highways, our first master plan had no firm recommendation, other than a short-range program for freeway routes. It presented an extensive network of expressways that nearly covered the map of New York State; but this was not a plan, just long-range speculation. In the second master plan we will present the results of a freeway corridor study that recommends a much reduced freeway plan for 1990; when the Interstate and other committed freeways are built, the major intercity corridors will be largely taken care of.

Significantly, therefore, in the second statewide plan our attention is turned to the important question of the adequacy of the 75,000 miles of other rural highways. These provide access to rural residents, businesses, recreational areas, and farms; and their service in terms of speed, safety, gradient, and operating conditions varies considerably. It is not our intent to recommend a "plan" for these smaller scale facilities but, more significantly, to recommend standards and programs. Our work in the National Transportation Needs Study has shown that improvement of rural roads to the "ideal" standards set by the Federal Highway Administration would cost more than was anticipated by the highway-program resources or perhaps is even desirable. We are, therefore, examining alternatives to these standards and will be devising more reasonable standards that are commensurate both with the resources expected to be available and, perhaps more difficult, with the benefits provided.

For freight transportation, the first statewide plan had very general policies. Although we have studied freight transportation in more detail for the second statewide plan, our recommendations for freight transportation are not portrayed by additional maps of needed facilities—such as rail lines or truck terminals. Facilities are not so significant as service, as measured by speed, frequency, appropriate schedules, reliability, safety, and especially economy. These are operational questions and are so complex that they are beyond the present ability of government and should perhaps be left ultimately to the private companies that conduct the operations. Our concern is more with the governmental policies and actions that affect the relative treatment of these companies, the potential for profit or even existence of private modes, and thereby the quality of service.

If government can foster an economically viable private transportation industry and treat competitors equitably, there will be a rational allocation of freight by mode; and such problems as boxcar shortages or track maintenance will take care of themselves. In this regard, we concur in general with the National Transportation Policy, released in 1971 by the Secretary of Transportation, which would place greater reliance on the forces of the competitive market in setting the cost and the level of transportation service.

For railroads, for example, this means consideration by the state of local tax changes. It means the elimination of many uneconomical branch lines; but where it is determined that there is a developmental or other social need for service, even though it is uneconomical, the service should be supported by public funds rather than by the company or users of the service.

For trucks it means the state is reducing or eliminating restrictions on entry and exit for regulated motor carriers, giving more freedom to the carriers to set individual rates, and eliminating other administrative and legislative restrictions on service.

For waterways (and in New York State we are unique in owning a 500-mile canal), it means, in addition to questions of system extent and facilities, the question of charges to canal users.

For ports it means concentrating on the financial and facility needs of public ports. Private ports handle more than 90 percent of New York State's port tonnage, but their facilities are privately supplied and require little state attention, a distinction not emphasized in the first statewide plan. There are 6 ports owned and operated by local government or public authorities, 5 in the upstate area and the Port of New York. Their future financial viability and the state's role will be a major concern of the second statewide plan.

New York's statewide plan is not only devoted to intercity systems but also includes urban transportation. Statewide planning involves not developing urban plans (the responsibility of the several urban transportation studies in the state) but reporting on them and assessing them from a statewide view. The second statewide plan will, therefore, contain, as did the first, a major urban-transportation element. It is much more detailed now, reflecting the completion of many urban transportation studies; these have produced major facility recommendations and have entered their continuing phase.

When the results of urban transportation planning are viewed statewide, however, new questions are raised. Have the values assumed for plan development, and especially their relative weights, altered by the passage of time? The question applies not only to construction costs, which have inflated significantly faster than user savings in the past decade, but also, and more important, to the environmental and social costs attendant on new construction. From the public response evidenced in the last decade, the latter received far from sufficient weight in plan decisions.

Another question to ponder is, Have operating problems and solutions received sufficient attention in urban transportation plans? Improvements to the operation of existing facilities were not the thrust of those studies. Improvements to traffic flow on existing streets, peripheral parking, priority transit lanes on expressways and streets—these are alternatives only beginning to be fully explored and applied.

For transit, similarly, our attention was on facilities, such as new express bus or rail transit lines. Questions of operating subsidies to permit improving or maintaining the quality or extent of local transit service, or to eliminate fares altogether, have rarely been considered, although, in terms of need and benefit, they are valid alternatives for the investment of public resources.

I think it is now apparent that New York's second statewide plan will be far more than a map of new capital facilities. It must concern itself with major and difficult questions of resource allocation between highways and public transportation, between urban and rural programs, and between capital and operating assistance; and it must address questions of the appropriate state involvement in freight transportation. The second report, therefore, while containing more detailed and specific recommendations than the first, raises many new questions as well—questions that, because they concern value judgments and new public responsibilities, involve citizens and their leaders as well as professional transportation analysts and planners.

Therefore, the second report will be different from the first in another, equally significant, way. Rather than issue a single, final report, we plan to release a draft report early in 1972. We want to provide for widespread public review and examination of the results of planning studies and to describe, as frankly as we can, their basis and assumptions. There will be public hearings in many areas of the state, therefore, at which special-interest groups, local government officials, political leaders, and the public at large can make known their views of our recommendations. Only after these hearings and the modifications made as a result of them will the final version of the second statewide plan be completed.

A COMPARATIVE ANALYSIS OF STATEWIDE TRANSPORTATION STUDIES

Philip I. Hazen, Federal Highway Administration, U. S. Department of Transportation

This report reviews the 5 statewide transportation studies undertaken by Iowa, Wisconsin, Rhode Island, Connecticut, and California (study design). The studies are compared and rated as to the amount of effort expended in study design, data collection design, model development, forecasting and testing of alternatives, and implementation. Iowa spent 6 months and $9,000 of outside computer services to develop a future trip table and assign it to the present and committed highway system. Wisconsin spent 2 years and more than $100,000 in wages and computer services to develop and test alternatives and to develop a final state highway plan. Rhode Island and Connecticut spent more than 5 years and $1 million each to develop comprehensive statewide transportation studies that are strong in data collection, socioeconomic forecasting methods, and sophistication of the land use and travel models. These studies were grouped into classes that represent a cost level in which the effort is balanced among data collection, modeling, and plan development. The classes can be used as a guide by states considering a new study.

•STATEWIDE transportation studies based on statewide traffic assignments are a natural outgrowth of urban transportation studies. Ten years ago it was recognized that the urban areas lacked detailed planning information and studies that would determine what highway facilities should be built and where they should be located. At that time the rural areas had a large source of planning information from the highway planning surveys, which have been conducted since the mid-1930's, and were generally satisfied with the functional classification and needs studies, which recommended what highway facilities were needed and what their approximate locations should be. Urban transportation planning has come a long way in 10 years, and the states now need to make use of the procedures and models for comprehensive planning. These new tools applied at the state level should improve the present state functional classification and needs studies and lead to better decision-making.

Furthermore, interregional traffic patterns are in need of investigation as much as intraregional traffic patterns. The planning of an urban transportation network is deficient unless it takes into account the planning of interregional arterials leading into the urban area. It is believed that a good state transportation plan can provide the framework for good regional and local planning. A statewide transportation plan provides a means of coordinating capital improvements with the activities of other state agencies, and it provides a means for a balanced allocation of projects in the many regions and urban areas of a state. Furthermore, the goal of the state should be an efficient transportation system that will best serve the statewide movement of both persons and goods and promote desirable state development patterns.

To better understand what constitutes a good statewide transportation study, the author has selected for description 5 out of the 23 studies listed below:

Status	Study
Developed and tested future-year plans	Wisconsin
	Rhode Island
	Connecticut
	Delaware

Status	Study
Assigned future-year trips	Iowa Illinois Arizona Pennsylvania Michigan Minnesota
Assigned base-year trips	Missouri Tennessee California
Have started studies	South Dakota Oklahoma West Virginia Wyoming New York Kentucky Nebraska Georgia Florida Mississippi
Selected for description	Iowa Wisconsin Rhode Island Connecticut California

The 5 states were selected because they have completed their initial study objectives, and their outputs are close approximations to completed statewide transportation studies. In addition, the studies were selected for comparative discussion purposes because they vary in degree of sophistication from the simple statewide traffic model completed in Iowa to a study design incorporating the systems analysis approach to be used in California in a future integrated statewide transportation study. The Wisconsin, Rhode Island, and Connecticut studies fall in between the Iowa and California studies. Although simple model techniques were used in Wisconsin, very good planning techniques were used in testing of alternative systems, selecting the final plan, and taking steps for implementation. Rhode Island and Connecticut are using sophisticated model techniques and are performing comprehensive statewide transportation studies that will also satisfy the requirements of the 1962 Federal-Aid Highway Act.

The author's opinions regarding the strong points and the limitations of the studies are discussed. A complete description of the respective studies is given in reports published by the respective states or elsewhere (1).

IOWA

Iowa completed the first known statewide traffic assignment (2). State highway department personnel performed the work between November 1963 and May 1964 and used about $9,000 in outside computer services.

Data on trips made by automobiles and trucks were obtained from the Mississippi Valley multiple screenline origin and destination survey (MVOD) conducted in 1959 and 1960. Trips recorded from the 132 interview stations were combined with data from 292 interview stations that were part of the external cordons of urban transportation studies. The data from these stations were edited, factored to ADT and to the 1960 base years, and combined into a statewide trip table.

In Iowa, trip ends were coded to cities and villages with place names. Each village with more than 150 people was made a separate centroid. The villages with fewer than 150 people were grouped with the nearest village with more than 150 people. This resulted in 855 internal centroids and 72 external stations at the stateline, a total of 927 centroids.

The base assignment network for 1960 included 10,221 miles of Interstate and state primary highways and selected county roads. The committed assignment network included these roads plus all proposed Interstate highways and all other completed and programmed improvements after 1960.

The zonal population was forecast to 1980 by using the step-down ratio method. A forecast of the statewide trip table to 1980 was made by the Fratar method. The projections of trips between all zones were based on the 1980 to 1960 ratio of population for each zone modified by an overall state factor for increased automobile ownership and increased travel projected for 1980.

Some experts consider the Fratar method to be weak in handling small volumes, unable to handle zero volumes superseded by new access or large population growths, and weak in contributing to the understanding of travel behavior. On the other hand, the Fratar method does well where the travel patterns do not exhibit large changes from the base year to the forecasting year, and the Fratar method is easy to apply. This appears to be the case in Iowa. The resulting assignment was used to prepare the 1965 Interstate cost estimate and to test alternative locations of I-35 in north central Iowa.

Major Good Points of the Study

1. The study accomplished its original objectives of obtaining a statewide traffic assignment for 20 years into the future that would show diverted traffic to the Interstate System.
2. In terms of cost effectiveness the study was outstanding. It was accomplished with 6 months of work and $9,000 in outside computer services.
3. The study was performed by highway department personnel. Therefore, they had full cognizance of the limitations and could make further assignments as needed.

Limitations of the Study

1. The trip table is missing most of the short trips, trips under 10 min in length, or an estimated 24 percent of the system vehicle-miles of travel.
2. Iowa did not develop or test any alternative highway plans. The only system tested was the one programmed for construction.
3. Iowa did not develop a transportation plan or relate it to other state facility plans.

The discussion on limitations refers to the study design and says in effect that Iowa did not go far enough with the planning effort.

WISCONSIN

The Wisconsin Statewide Transportation Study was begun in April 1964, and the main effort continued until about December 1967 (3, 4). It was undertaken by state highway department personnel. Many reports have been published that document the study very well.

The base data were from the MVOD survey conducted in 1959 and 1960. There were 186 roadside stations at which 350,000 interviews were conducted. An attempt at synthesizing the trips in the areas bounded by the screenlines was unsuccessful, and the study proceeded with the basic 1960 MVOD trip table.

Zones were developed on the basis of townships; each township having a population of more than 1,000 people was made a separate zone. This gave 570 internal zones. Counties in the adjoining states, other states in the United States, and provinces in Canada accounted for 24 external zones. Forty-nine additional zones represented the external stations for a total of 643 zones.

The selected network included 10,434 miles of Interstate and state trunk highways and about 4,050 miles of county, town, and other roads for a total of 14,484 miles.

The study staff used the 1980 population forecasts developed by the Wisconsin Department of Resource Development (DRD). Two population forecasts had been developed. One was based on employment forecasts, and a second was based on demographic trends by the "short reliable" method. One was a low forecast, and the other was a high forecast when compared with independent sources. In addition, DRD admitted that its procedure had resulted in an underallocation of population to zones of a suburban character. A rather arbitrary set of rules was developed in order to select population from either the employment-based forecast or the demography-based forecast or the mean of both

of them. In addition, these forecasts were on a county basis and had to be allocated to the zones. This allocation was done on the basis of the 1960 ratio of township to county population and did not appear to account for the different growth rates among zones. Some upward adjustment of population was made to the suburban zones by using the demographic forecasts. The original county forecast was to 1980, and the highway department extrapolated the forecast to 1990 based on the 1960-1980 growth rate.

The Fratar method was used to forecast the statewide trip table. For automobile trips, the growth factor was based on growths of population, vehicle-miles, and recreational attraction. For truck trips the growth factor incorporated employment and vehicle-mile factors.

The development and testing of alternative highway systems were very extensive. The concept of functional classification was used to develop a hierarchy of systems as related to the hierarchy of cities and regions served. The staff generated 16 planning schemes in an attempt to look at a wide variety of ideas on highway systems. From these schemes the staff developed 4 alternatives based on different mileages and different configurations of the functionally classified highways.

The highway system objectives were refined to standards that were the basis of traffic service tests and land service tests. One traffic service test consisted of an economic analysis of alternatives applying automobile user operation and time cost of $3.50 per hour. Total capital costs and total user operating costs of each of the alternatives were computed and used for comparison purposes. Other traffic service tests consisted of comparing vehicle-hours of travel on each of the alternatives and the percentage of long-distance trips occurring on the functional classes of highways within each alternative. In the land service tests, travel times were computed between metropolitan centers and other metropolitan centers, recreational areas, centers of highest assessed valuation, primary wholesale centers, and decentralized manufacturing zones.

A textbook rule is that the alternatives should be broad enough to include the optimum solution. Wisconsin realized that its 4 alternatives might not contain the optimum solution. Therefore, the staff developed and tested a theoretical all-freeway network (15 percent of total roads and streets) to obtain the upper boundary of feasible solutions. They discovered (much to their surprise) that the all-freeway system would have a lower total annual cost (construction plus user operating costs) than any of their other alternatives. This resulted in the development of the semifinal plan with increased arterial mileage and level of service and with a lower cost in comparison with the all-freeway network.

The desirable features of the alternative plans were combined into one plan, the semifinal highway system plan. The semifinal plan was then modified by suggestions from the central office and district offices of the highway department and the results of the traffic and land use evaluations. The final plan was checked for compatibility with activity plans developed by other state agencies. All of the tests indicated that the final plan was an improvement over the alternatives.

The final highway system plan was approved by the State Highway Commission on July 7, 1966. Steps have been taken for implementation. The final plan was first refined into a freeway-expressway plan. Next a guide for access control was developed. After that, specific corridor analyses were being undertaken in areas under intense development pressure for refining traffic forecasts, obtaining a specific location, and incorporating the location on the Official Map or taking other means for preserving right-of-way. Legislation was drafted on the reservation of right-of-way.

Major Good Points of the Study

1. The planning methdology was well formulated in the development of highway system alternatives and the refinement of objectives into traffic and land service tests. A 15 percent freeway network was tested to obtain the upper boundary of possible solutions. The study was well coordinated by obtaining review comments from the districts and other divisions within the highway department, was conducted within the framework of other state planning activities, and was made compatible with other state agency capital improvement plans.

2. After the approval of the final highway plan, the staff proceeded to take several steps toward implementation.

Limitations of the Study

1. As with any screenline study, the trips with both ends within the same grid are not obtained. The trip data become less accurate as one moves away from the screenline itself.
2. Trip card factors must be adjusted for those trips that cross more than 1 screenline. Usually there is no way to know which trips have been recorded more than once. Therefore, factoring may introduce some bias into the sampled data.
3. The MVOD screenlines were not coincident with zone boundaries. Therefore, some trips were intrazonal.
4. The recoding of the MVOD trips to zones resulted in 50,000 rejects when the data were edited. Some recoding involved estimates as to the correct zone of origin or destination.
5. MVOD stations were not located on all highways in the assignment network. This results in some missing interzonal trip data in specific locations.
6. The population projection (5) was rather simple and was constrained by ranges of projected populations with a set of rules for selecting the final value. A future study should apply more resources toward making good socioeconomic forecasts at the zonal level.

RHODE ISLAND

Rhode Island is a unique state with 1,000 square miles of land area and the Providence-Pawtucket metropolitan area, which contained 660,000 of the 860,000 population in 1960. In 1961 the Providence Area Metropolitan Study was started with a home interview sample of 5 percent within the city and 10 percent in the rural fringe. Standard truck and taxi surveys were also taken. A land use survey was made of the entire state during 1960-61 by the Planning Division of the Rhode Island Development Council. The detailed land use field notes were generalized into 7 land use categories of manufacturing, agriculture, residential, commercial, recreational, and public and semipublic uses.

The Rhode Island Comprehensive Transportation and Land Use Planning Program started on April 1, 1964, and the main effort ran until March 1, 1968 (6, 7). The total budget for the period was $998,156. The study had a policy committee and a technical committee. The federal members were the Federal Aviation Agency, Federal Highway Administration (formerly Bureau of Public Roads), and Department of Housing and Urban Development (formerly Housing and Home Finance Agency). The Rhode Island members were the Department of Public Works, Development Council, Department of Business Regulation, Transit Authority, and 3 city mayors. A 6 percent home interview was taken in the non-Providence portion of the state. There were 497 internal zones and 53 external zones for a 550 total. Since the entire state of Rhode Island is laid out with census tracts, the internal zones conformed with enumeration districts for ease of grouping by census tract. A uniform coding system for the land use was established, and data were collected concerning above-ground floor uses.

Trip generation and attraction equations were developed for home-based work trips, home-based shopping trips, home-based social-recreation trips, home-based other trips, and non-home-based trips. These equations included the following socioeconomic variables by zone: total population, automobiles, housing density, total employment, trade employment, and service employment. The gravity model was used for trip distribution.

Rhode Island has 4,380 miles of roads and streets of which 71.2 miles are Interstate, 750 miles are federal-aid primary, and 780 miles are other state highways—a total of 1,600 miles on the state system, and all of this constituted the assignment network. The highways were coded as expressway, arterial, and local.

The 1990 state population was forecast by using the cohort survival method (8, 19). A step-down procedure was used to determine zonal estimates. The zonal population

forecasts were checked against the holding capacities of existing amounts of vacant land in the zone, and modifications were made where necessary. Trends were used in projecting labor force, dwelling units, median income, and housing density.

Industrial land use was coded to 1 of 7 categories. Future industrial parks were ranked by priority based on services available. It was assumed that a certain percentage would be filled within each priority group for the forecast year.

Since the study's conception, the staff has been applying the same long-range planning techniques and data to solving immediate problems and high-priority needs. Specific projects completed by the staff include a preliminary design for a proposed bridge site on the Blackstone River, preliminary design for 5 interchanges, state poverty program study, forecast state electric power requirements, statewide plan for refuse disposal, statewide plan for water service, and statewide plan for historical preservation.

As a result of the findings of the study, Rhode Island has been very successful in obtaining various federal grants. A grant of $900,000 and a loan of $3 million were obtained from the U. S. Department of Housing and Urban Development to modernize the bus transit system in Providence. A demonstration grant was obtained from the U. S. Department of Transportation for a rail-bus vehicle project. A direct grant and a loan were obtained to purchase open space for recreational purposes. Another grant was obtained to develop a community civil defense shelter plan.

Major Good Points of the Study

1. The study has been successful in applying comprehensive urban transportation planning techniques to the entire state. This includes the collection and forecasting of socioeconomic data by sound planning techniques.
2. The study is popular with the local officials since it has stressed specific project planning services requested by the officials.

Limitations of the Study

1. The home interview data collected outside the Providence-Pawtucket metropolitan area was not used except to check the validity of the previously synthesized model.
2. The study is weak in evaluation of alternative highway systems leading to the development of an optimal transportation plan. Initially the state had relied on deficiencies to develop the future expressway and arterial plans.
3. The study used standard, well-documented procedures in all of its activities. The staff did this on purpose to avoid costly, time-eating research and to emphasize service to immediate problems. On the other hand, new and sophisticated planning techniques can also be put into a project control system. As the staff completes most of the basic studies, it is expected that consideration will be given to new areas such as the rail-bus demonstration project performed in 1968.

CONNECTICUT

On October 17, 1963, the Connecticut Highway Department and the Development Commission executed an agreement to do a statewide analysis of land use and transportation. At that time, the Commission had completed a statewide land use inventory. The Connecticut Interregional Planning Program (CIPP) was expected to cost more than $1 million, of which $606,000 was financed by a U. S. Housing and Home Finance Agency grant. The original study life was 3 years and was extended. Six general reports have been published (9, 10, 11, 12, 13, 14); technical reports are available on request. The study is composed of the following 5 major parts.

1. Goals and objectives—In conjunction with the home interview survey an attitude survey was conducted. The staff reviewed statements made by the legislature and mayors as reported in the newspapers. The attitude survey and public statements were used for the development of a comprehensive set of goals and objectives (9, 10) covering transportation, land use, housing, and recreation.
2. Economic base model—The competitive position of Connecticut in relation to 12 other nearby states was evaluated. A survey form was mailed to 2,000 companies, and

83 percent responded. In those 35 industries showing very high and very poor growth rates, interviews were conducted to determine more significant factors affecting the future of that industry. This resulted in an industrial accounts model to determine the employment in the basic industries and dependent employment in the related service industries for 25 industrial categories. This resulted in a state total forecast for employment, labor force, and population. The town growth distribution model grouped the 25 categories into 6 categories of manufacturing, retail, service-business, service-professional, construction, and other employment and distributed the 6 employment categories to the 169 towns. The zonal growth distribution model grouped the service-business and service-professional and grouped construction and other employment. The 4 categories of employment were distributed to zones. The population forecasts were modified based on the relative size of the total change in forecast employment.

3. Land use distribution model—The 1963 land use information collected by the Development Commission was incorporated into the study. The undeveloped land in Connecticut was inventoried. The potential for development was determined by measuring various site characteristics including location, accessibility, availability of water and sewer, soil type, slope, and drainage. The model takes state aggregates of population and employment supplied by the economic base model and distributes the aggregates to subareas. A simultaneous equation system was developed to allocate land uses to 4 economic sectors: manufacturing, service, unique locator (e.g., hospitals), and population (e.g., residential use).

4. Recreation model—A 1 percent sample of the automobile registrations was surveyed via telephone to obtain travel data for Sundays in August for the hours of 3:00 to 7:00 p.m. These data were used to develop a recreation model to determine demand in relation to accessibility of recreational areas. Connecticut was interested in evaluating the concept of providing adequate recreational areas within 25 miles of the cities.

5. Transportation models—Travel forecasting models were developed for 10-year increments beginning with the year 1960 and ending with the year 2000. Goods movements models were developed for railroad and truck. A highway priority construction model is to be developed.

Connecticut had a 1960 population of 2,500,000 spread among 169 towns and 2,800 enumeration districts. The state was subdivided into a 1,725-zone system and an 804-zone system. The zones were developed by using enumeration district boundaries and population, land use, natural barriers, and traffic assignment considerations. There are 52 external stations that, when added to state zones, result in a total of 1,777 and 856 in the respective zoning systems.

The network for the 1,777-zone system contained 9,100 miles; the 856-zone system contained 6,900 miles of highways. Both networks contained the state system of 3,700 miles and all expressway and arterial highways. The principal test network was the 1970 committed highway network.

Existing data from home interviews conducted in the early 1960's in the Waterbury Area Transportation Study, Southeastern Area Transportation Study, and the Tri-State Transportation Study (Connecticut portion) were used. The staff conducted a home interview (1 percent sample) in the remaining unsurveyed areas of the state. This resulted in 3,200 interviews of the total 8,300 interviews from all sources. Trip generation and attraction equations were developed from the home interview and the socio-economic data. The gravity model was used for trip distribution.

Data on goods movements by truck were obtained by interviews with truck owners and at roadsides at the state boundary stations. A 4-month sample of goods movement data by railroad was obtained from invoices from the New Haven and the Central of Vermont Railroads. The data included commodity, origin and destination, number of cars, weight in hundred pounds, and whether inbound, outbound, or local.

It did not appear that the development and testing of alternatives received the level of effort that the model development and other parts of the study received. One report (15, p. 15) states, "Of the main factors to be considered in determining the need for a new or expanded highway facility, the volume of traffic using the existing facility is generally accepted as the best indication of need." The report continues (15, p. 19),

"The 'committed system,' used as the base network, was considered to remain static for the purposes of determining future deficiencies." Later in the report, deficiencies are determined and two sketch plans, grid analysis alternate and network analysis alternate, are shown. Also 2 other figures, the composite of regional plans and Connecticut Highway Department long-range proposals, are added to the alternatives.

The state considers the committed network to have a high probability of being carried to completion. That is, it represents a highway system that is "constructed, under construction, or has financing authorized for construction and/or engineering and rights-of-way acquisition."

The committed system was loaded with 1970, 1980, 1990, and 2000 traffic. The results were analyzed, and plan improvements were added consecutively by decade taking into account, on a subjective basis, the increased accessibility from the previous improvements. This resulted in the Connecticut expressway test plan (15, Fig. 14). The composite of regional plans was tested by using CIPP forecast land use as well as the socioeconomic data supplied by the 11 active regional planning agencies. This was a coordinated effort between the Connecticut Highway Department and the regional planning agencies.

At present, it appears that the staff has limited itself to satisfying deficiencies. Alternatives should be developed on a sufficiently broad basis to cover the optimum solution. As an example, alternative transportation plans may be developed to serve the alternative land use plans and reflect different levels of service to regional centers within the state. To date the study has not applied its own transportation goals, such as "bring elements of the community closer to each other," and its objective, "reduce time and distance of travel." Also, the figure of $3 billion in highway needs for the future mentioned in the report, A Plan for the Future (Partial), has differed little from the figure of $3 billion of needs mentioned in the report of Klar and Resnikoff (16, p. 186) and in the report, The Long-Range Plan of Connecticut Expressway Network, January 1965. The state says that this has occurred primarily because most of the anticipated growth in the state is expected to occur in the southwest and central corridor. The central cities are expected to continue as major attractors in the future. This results in major corridors of travel emanating from the cities as well as connecting them.

Major Good Points of the Study

1. Connecticut has undertaken a comprehensive study that has included sophisticated planning models. The latest developments in land use distribution models appear to have been used. Supporting the land use model is the very detailed inventory of existing land uses within Connecticut. In addition to the information collected on present use, the study has collected characteristics of undeveloped land for future use.
2. The sophistication and the detail of economic analysis are equal or superior to any of the current statewide economic studies. Connecticut developed what it believes to be comparable to an input-output model of the state.
3. The goals for Connecticut appear to be well researched by the attitude survey and in newspapers. The goals also appear to be formulated and clearly explained in the reports.
4. One goal for open space, natural resources, and recreation is, "Provide recreation as near as possible to concentrations of population." The staff has mentioned during discussions the figure of 25 miles as being the desirable limit for providing adequate recreational opportunities for the residents of an urban area. This is very desirable.
5. Connecticut also discovered that its design-hour volumes were occurring on Sunday afternoon, between 3 and 7 p.m. Thirty and 40 percent of travel during these peak hours are for recreation and social purposes respectively. A recreational model was developed to provide forecast recreational travel that improves the information available for design purposes.

Limitations of the Study

1. A 1 percent home interview sample was insufficient to provide an origin-destination trip table that when expanded and assigned to the network would give a good comparison with average daily traffic. Since several zones in the rural areas had less than 30 interviews, they had to be combined with adjacent zones in order to develop valid statistical relations. In spite of this limitation, the use of the origin-destination information in trip generation, trip distribution, and traffic assignment resulted in a match of 93 to 95 percent between assigned volumes and average daily traffic on 4 screenlines and 3 urban cordons. The staff is generally satisfied with the sampling rate.

2. The development and testing of alternative plans has not received the level of attention that other parts of the study have received.

3. Although apparently the staff provides information to design, the work on the construction priority program appears to be suspended, and the state still appears to hold back in recommending a highway plan.

CALIFORNIA

In late 1964, a request for a proposal was issued by the California Department of Public Works, Division of Highways, for the development of a work program that would establish the content and specifications for a systems approach to the solution of California's basic transportation problems. Subsequently, North American Aviation, Inc., was awarded the contract for $100,000. The project resulted in a 5-volume study design (17).

The study design proposes to use the systems analysis approach. The transportation system would be one subsystem within the California system. The transportation model was defined in a familiar way with submodels of population, economy, land use, transportation demand, transportation simulation, and evaluation. Each submodel would be designed with interfaces with the other submodels within feedback loops. They would operate in small increments of time so that feedback can occur between the submodels and take account of the dynamic nature of the system and the interrelated effects. Each submodel would use the latest forecasting techniques, such as, an input-output model for the economy submodel.

The study design states that there would be a low probability of accomplishing the study for $5,932,000 and a high probability of accomplishment for $9,200,000 within a study period of 52 months.

There is disagreement as to whether the advantages of the proposed systems analysis tools are worth the additional costs above the costs of the traditional methods. The arguments, pro and con, are beyond the scope of this report. In the author's opinion a systems analysis approach, if undertaken, would be most applicable to a dynamically growing, complex state, such as California.

In any case, the Division of Highways has not taken any steps to improve or implement the study design. However, there was recognition by various personnel within the division that some form of statewide model was needed. In late 1969 the central office staff responsible for the urbanized area transportation studies was given the approval to develop a statewide model.

A 1966 statewide trip table has been synthesized by extending the trip generation and trip distribution models developed in the 5 large urban area studies: Los Angeles, San Francisco, San Diego, Santa Barbara, and Sacramento. The statewide model has 1,600 zones and a network including the state highway system of 14,215 miles plus additional feeder roads.

A recent publication (18) gives a later study design using the systems analysis approach. The Pennsylvania study design builds on the California design and the investigations undertaken by the Northeast Corridor Project. The recommended study for the proposed Pennsylvania Department of Transportation has an estimated cost of $7,150,000 during a 5-year life.

Major Good Points of the Study

1. The study has feedback loops to account for the interrelatedness between land use and transportation systems. Most studies realize that the building of transportation systems will in turn affect the land use development patterns; the staff usually attempts to guide the land use development by restricting transportation facilities to certain corridors. On the other hand, few studies have tried to take account of the magnitude of the effects on the land use pattern resulting from the new transportation facilities.

2. Individual person and commodity movements will be studied. This allows emphasis to be placed on improving terminals for intermodal transfers. It should also allow for a better match between person or goods movement requirements and transportation system characteristics.

3. The systems analysis approach appears to be best for incorporating the analysis of new modes. In Volume 4 (17), the consultant presented an example analysis of petroleum movements and duplicated the threshold value reached and the shift from truck to pipeline that occurred in 1965. Likewise it is believed that transportation demands can be matched with new modes of travel, such as short takeoff and landing aircraft and hydrofoil ships.

Limitations of the Study

1. The process is considered to be cumbersome since it is a "forward seeking" model in that it goes forward in time and relies on the output from each period to set the requirements for transportation facilities and to give inputs for the succeeding period. Simulation usually requires a lot of data and quickly uses up many hours of computer time and generates masses of data. Large volumes of output are usually obtained and has to be evaluated to ascertain that it is reasonable.

This iterative procedure appears to be the best method of population forecasting using the cohort survival method or similar technique. Also the iterative procedure appears to be the best method for economic forecasting using the input-output model.

On the other hand, the advantages are not certain for land use forecasting and the respective transportation system to serve the new land uses. An alternative is the "goal directed" approach that sets forth alternative plans for the future year and investigates "backward" to see what the demands will be.

2. The California study does not propose any methods for overcoming some problems. The first step in systems analysis is to define the mission or objectives of the system. Normally the transportation planner will use a benefit-cost ratio framework. But what about conflicting objectives in the areas of safety, air pollution, noise, amount of land removed from tax rolls, and level of service? The study design did not help the evaluator who must be able to put the objectives in a framework where the decision-maker can evaluate trade-offs.

3. A major flaw was that airline distance (17, Vol. 3) instead of true network distance was proposed for the transportation demand model (commodity demands). Airline distance is not a network dependent variable, and therefore changes in the network cannot influence the commodity flows.

CLASSIFICATION OF STATEWIDE TRANSPORTATION STUDIES

The statewide transportation studies based on statewide traffic assignments differ among themselves in the type and scope of problems they attempt to solve. They also differ in the amount of resources—personnel, budget, and available data—that can be applied to the study. Limited resources require that the problem definition be put in a narrower context than it would be were more resources available. After the scope of the study has been determined, a balance should be determined among the effort spent on data collection, model development, and final plan development. Administrators are usually interested in completed studies that come to conclusions, i.e., a recommended plan. Table 1 gives the differences among studies, which are grouped into 4 classes, and should aid new studies in achieving a balance among data collection, model development, and final plan development.

Table 1. Classes of statewide transportation studies.

Class	Objective	Procedures
Statewide traffic model, $100,000 or less, 6 to 18 months	To do system simulation using computer to better understand how system operates (results are used for functional classification and general planning purposes)	Zones and network are selected and coded by using standard procedures; models for trip generation and distribution are kept simple, i. e., usually no trip purpose breakdown, usually 1 but not more than 3 independent socioeconomic variables, and minimum O-D data
Statewide transportation study (highway), $100,000 to $500,000 (usually more than $200,000), 15 to 30 months, 6 to 12 personnel	To develop intermediate-priced traffic model based on O-D sample design; to obtain good information on trip generation and trip length; to evaluate alternative highway networks; to develop state highway plan	O-D sampling for internal trips is accomplished by multiple-screenline roadside interviewing, stratified, cluster sample of homes, telephone interviewing, or comparable procedure; models are developed by trip purpose, usually automobile (3-5) and truck (1-2); comparisons and calibration are made against ADT volumes; development of alternatives includes functional classification, scheme development, and testing
Comprehensive statewide transportation study, $500,000 to $1,500,000, 24 to 48 months, 10 to 25 personnel	To develop on statewide or regional basis comprehensive transportation planning process; to simulate person movements by mode of transportation; to evaluate alternate modes and networks; to develop state transportation plan	Elements and procedures are similar to those in comprehensive urban transportation studies, interviews are sufficient to develop trip table of interzonal person movements; studies include economic base model and land use model; within budget limitations, goods movements would be obtained and projected
Integrated statewide transportation study, more than $1,500,000, 36 to 60 months, 15 to 50 personnel	To apply latest techniques in systems analysis and operations research to statewide transportation planning; to study complete system of person and goods movement from origin to destination; to evaluate alternate sets of policies in regard to transportation system; to develop state transportation program	Procedures incorporate latest techniques in systems analysis and operations research; detailed person and goods movement from origin to destination are studied with emphasis on transfer and terminal points; models are iterative with feedback to account for results of different transportation policies

The different classes of studies are compatible with one another. They proceed from the simple studies to the more complex studies. The simple studies can be used as an educational device before a complex study is done. The initial study, a statewide traffic model, contains detailed zoning and detailed highway network development. This is the same detail that is used for the larger studies. In addition, the state-line cordon is common to all studies, and data are collected on through trips and interstate trips.

The second class of studies, the statewide transportation study (highway), could be extended to the other transportation modes, such as railroad, air, and waterways. In looking at the other modes of travel, one could make a detailed analysis at congested terminals.

The statewide traffic model is a study similar to the one undertaken by Iowa. It is applicable to a state with rural characteristics and static or slow economic growth. Also, it can be undertaken as an educational process where statewide planning is not very sophisticated. The framework of the study provides a basic zoning and network development for current and future use. The MVOD data used by Iowa probably cost $95,000 but consisted of existing information that was 3 years old when it was used. If data are collected, it is suggested that external-external (through) trip and external-internal (interstate) trip data be collected at a state-line cordon. It is recommended that internal travel be synthesized from existing data. In most cases, the travel forecasts will be based on the 1 variable—population. If additional socioeconomic variables are used, a second variable can be an economic variable to account for influences other than that of population (perhaps car ownership or employment), and a third variable can be recreation attraction (annual visitations to a zone), which accounts for activity in addition to both population and economic variables. The study should result in a functionally classified network and synthesized future traffic volumes. Other studies classed as statewide traffic models include those that have been completed in Arizona and Illinois and those that have begun in Oklahoma and South Dakota.

The statewide transportation study (highway) is similar to the study in Wisconsin. This study would be undertaken by states with moderate growth or states developing

separate studies for each of the tansportation modes. The state uses moderately priced O-D sampling techniques and moderately priced population and economic forecasting techniques. The state spends a considerable effort, perhaps one-third of its resources, on the last phase consisting of developing and testing alternative networks, developing the final plan, and taking steps for implementation. Most states currently undertaking a study are grouped in this category of statewide transportation study (highway). These include, in addition to Wisconsin, Delaware, Georgia, Kentucky, Michigan, Minnesota, Missouri, Nebraska, Pennsylvania, Tennessee, West Virginia, and Wyoming.

The comprehensive statewide transportation study is similar to those studies undertaken by Rhode Island and Connecticut and initiated by New York and California. Probably this study should be undertaken by states with wide urbanization or with adequate funds to obtain a complete trip table of interzonal person movements. This would normally be the first class of study to develop a general land use plan separate from the forecasts of socioeconomic variables and to use commodity movements instead of the number of trucks. A considerable part, perhaps one-third, of the resources should be devoted to the developing and testing of the land use and transportation final plans.

The integrated statewide transportation study is similar to the study design for California. This study looks at transportation demands in terms of the characteristics of the origin-destination, time requirements, and cost requirements for person movements and commodity movements. This study has the resources to look at very detailed movements and requirements at intermediate and final terminals. Again a considerable part, perhaps one-third, of the resources should be allocated to development of the land use and transportation final plans.

COMPARISON AND ANALYSIS

A comparison of statewide transportation studies of Iowa, Wisconsin, Rhode Island, and Connecticut points out the strong points and limitations of the respective studies. The comparison is only relative since the studies represent different levels of effort and therefore a different class of study as discussed in the previous section. Table 2 gives ratings of the studies based on accomplishment. The numerical ratings are defined as follows:

Accomplishment	Rating
High	3
Medium	2
Low	1
Nothing	0
Unknown	?

Table 2. Comparison of statewide transportation studies.

Major Parts	Iowa	Wisconsin	Rhode Island	Connecticut
Study design	2	2	3	3
Goals and objectives	0	2	2	3
Data design	1	1	2	2
Model development	1	1	3	3
Forecasting				
Population variables	1	1	3	3
Economic variables	0	0	2	3
Land use distribution	0	0	2	3
Testing of alternatives				
Transportation alternatives	0	3	1	1
Land use alternatives	0	0	?	?
Implementation				
Freeway-expressway plan	2	3	2	2
Access criteria, right-of-way	0	3	1	1

Note: The studies are all compared against a theoretical ideal study that, of course, does not exist, but the comparison has the advantage of illustrating the strong points and limitations of the studies.

Study Design

All studies had good study designs. In each study, a straightforward application of study resources was made in accomplishing the study objectives. Connecticut had a good study design in terms of innovative methdology and interrelating future population, employment, and land use distributions.

Connecticut developed and applied the critical path method (CPM) to keep the study on schedule and to efficiently employ the personnel who occasionally numbered more than 30. The study staff in Rhode Island spent considerable time during the initial phase specifying the problems and the goals, developing work elements, and analyzing work flow. The work flow analysis used the program evaluation and review technique developed by the U. S. Navy in scheduling personnel and activities. Rhode Island was probably the most successful in completing work phases on time.

Wisconsin developed and applied the CPM to keep its study on schedule for more than 28 months. It is believed that Iowa did not develop a detailed schedule since the intensive effort was during a short period, 7 months, and the number of personnel was small so they could have daily contact. It should be noted that the study design in Connecticut, Rhode Island, and Wisconsin was not a "fancy" prospectus that sat on the shelf but a CPM that was developed by the staff, in blueprint or technical report form, and revised on a regular basis.

Goals

Connecticut, Rhode Island, and Wisconsin developed an extensive set of goals and objectives. Connecticut did possibly the most work in goal development, and that is reflected in 2 well written reports (9, 10). Goals are discussed at the personal, city, regional, and state levels. The state goals are categorized as follows: economic, urban form, transportation, open space-natural resources-recreation, and housing.

Rhode Island's goals can be categorized as follows (6, 7): transportation; orderly land use development; solution to transit problem; and satisfy federal requirements for urban transportation planning, transit grants, and recreation grants. In addition, Rhode Island wanted to establish a continuing, cooperative, and comprehensive process for better master planning at the state and local levels.

Wisconsin developed a set of objectives for a safe, efficient, and economical highway system that is integrated with other modes and coordinated with land development.

Coordination

The studies in Connecticut, Rhode Island, and Wisconsin were cooperative, coordinated efforts. The Connecticut Highway Department (now the Department of Transportation), Development Commission, and Department of Agriculture and Natural Resources were joint sponsors. The regional planning agencies were major contributors of data and plans, and one alternative system was a composite of regional plans.

In Rhode Island, coordination was achieved by a policy committee and a technical committee. The committee membership included 3 federal agencies, 4 state agencies, and 3 city mayors. One particular goal was to conduct seminars for state and local officials concerning computerized planning tools and data banks.

The Wisconsin state highway plan was developed as one of several statewide studies being coordinated by the Wisconsin Department of Resource Development. The highway department coordinated efforts with the Southeastern Wisconsin Regional Planning Commission, which was responsible for a recommended system plan within its area. Other urban studies were coordinated since the state staff was also responsible for their development. Later planning in Wisconsin included the other modes.

O-D Data Collection

No state had the best data collection design. Rhode Island did home interviewing at the usual sample rate of 5 to 10 percent based on high to low density of dwelling units. This sample rate gave a valid statewide trip table of surveyed trips, but it was expensive. Connecticut used primarily a uniform 1 percent home interview sample. The

1 percent sample provided data for trip generation and trip distribution equations. It appears to be the best initial effort in developing a compromise between expensive large surveys and inexpensive surveys collecting very few data. Wisconsin and Iowa used the large source of existing roadside data. It was inexpensive, but the studies had to compensate for the limitations of the data.

New studies, which are not so urbanized as those in Connecticut and Rhode Island and which undertake a statewide transportation study (highway) as defined previously, are expected to use one of the following examples: Minnesota and Nebraska interviewed at urban cordon roadside stations in urban areas with 600 population (Minnesota); Delaware conducted a 10 percent telephone survey outside of Wilmington; and Kentucky is conducting a 1.75 percent mail survey based on vehicle registrations.

Model Development

Both the gravity model and the Fratar method appear to give satisfactory results if adequate data are available and the models are properly calibrated. In Connecticut and Rhode Island, trips were related to detailed breakdowns of population, employment, and land use. The trip distribution was by trip length frequency obtained from the home interview survey. The procedures were similar to those of urban transportation studies using the gravity model.

Iowa and Wisconsin used the Fratar method, which requires a complete or nearly complete O-D trip table for the state. The growth factors usually are simple; in Iowa and Wisconsin they were primarily based on population.

Connecticut and Rhode Island collected recreational travel data, and Wisconsin used a recreational growth factor. Recreational travel now determines the design-hour volumes on many rural highways, and its importance is growing as incomes and leisure time increase. Most states factor average daily traffic to design-hour volume because historical data are available on factors. However, weekday data are not similar to weekend data. If weekday data are factored to ADT, they introduce considerable biases in trip purpose, trip length, car occupancy, and O-D patterns. Therefore, other states may follow the examples of Connecticut and Rhode Island and collect recreation or weekend travel data.

Forecasting

It is considered that Connecticut had the most sophisticated efforts in forecasting with the economic base model and the land use allocation model. Rhode Island used the cohort survival method to develop a state forecast of population.

Although the procedures in Iowa and Wisconsin were simple, the population forecast was controlled at the state level, and allocation of future growth to urbanized areas and regions had to be realistic and represented difficult choices as to which areas would grow very little.

An economic base model patterned after those of Connecticut, Rhode Island, or another study is very desirable. Economic activity levels for future years provide a basis for future employment forecasts.

Instead of using a land use model, most states will be looking at future resource use, development patterns of cities and regions, and preservation of environmental areas. In highly urbanized states, land use is quite important in definition of intensity of use and specific category.

Testing of Alternatives

Wisconsin developed specific evaluation criteria from its highway system objectives, which were categorized as traffic tests and land service tests. The alternative highway plans were developed after consideration of many planning schemes and were based on different levels of service. Several traffic and land use tests were applied to the alternatives. In addition, an all-freeway plan was tested. The final plan was developed by combining the best parts of all the alternatives. The study staff developed a final plan that reflected a high level of service with reduced travel time for the long trips so the cities and major centers were brought closer together.

It appears that both Rhode Island and Connecticut relied on deficiencies in the committed system developed by comparing the design capacities against the future volumes. No reports were published showing other tests.

Implementation

It appears that Wisconsin has done the most extensive work in the implementation area. The Wisconsin freeway-expressway plan has a good chance for implementation since it is an outgrowth of the final highway plan. Guides for access type and spacing criteria and revised geometric design standards have been developed as a result of the planning process.

Wisconsin has refined the final plan by performing corridor studies in the rapidly growing areas of the state and at other critical locations. This will tie down the specific location of the highway and permit some progress in reserving future rights-of-way, pending legislative approval of proposed legislation. A priority programming method has been developed and is now being tested in selected areas to see whether it is politically acceptable.

Connecticut is undertaking corridor studies to determine the optimum mix of various transportation facilities to handle the forecast demands. Connecticut listed as a specific objective to develop a "priority plan" (16, p. 186), and this is expected in the future.

CONCLUSIONS APPLICABLE TO FUTURE STUDIES

From the previous comparison some conclusions can be drawn and inferences can be made for future studies.

Effort spent on the study design is well worth the time and money. The study design should include a schedule such as a bar chart, critical path method, or similar tool.

Goals should be available or established for all state activities, and a subset of goals established for the transportation system. The study staff should develop the study objectives and the problems that will be studied. This indicates the purpose of the study and, along with the transportation system goals, provides the planning framework for subsequent technical activities. The goals and study objectives should be further developed into a set of evaluation criteria or performance standards for alternative testing and plan development.

The data collection design is important. State-line stations should obtain data on interstate travel. Origin and destination surveys for internal travel should be designed to make cost-effective use of existing and new data and to obtain statistically valid relations between travel and socioeconomic characteristics. Comprehensive studies should use home interviews to collect person trip data for all modes. Studies at a moderate level of effort are expected to use mail, telephone, or urban cordon roadside interviews to collect vehicle trip data for highways. Finally, where money is available for several, single-purpose studies, it is recommended that one multipurpose study be conducted where possible. For example, a state-line cordon could collect data on interstate travel, tourism, recreation, and interstate truck commodity movements.

The gravity model will probably be used by most states to develop statewide trip tables from the relation between travel and socioeconomic characteristics including the trip length. The gravity model or Fratar method may be used where urban cordon data provide a statewide trip table.

Connecticut and Rhode Island provided good examples of economic base studies and population and land use forecasting in a comprehensive statewide transportation study. At the moderate level of effort, most studies will not analyze land use, but regional and city development trends should be investigated. At the moderate level of effort, the following socioeconomic variables or a subdivision thereof will probably be used: population, employment, retail sales, and recreational activity. For most forecasting, a range with low and high forecasts is better than a single point forecast because of the large number of unpredictable factors. An economic base study or some level of economic analysis is encouraged to provide good future employment figures.

Rhode Island undertook immediate action projects. The immediate application of new data and the planning techniques to immediate problems can generate the support of management. Of course the immediate application must be successful and a proper

balance should be maintained between immediate-action planning and long-range planning so that the long-range planning effort is not delayed.

The alternatives should indicate the range in investment levels; the low boundary is the present system plus committed improvements, and the upper boundary is (in my opinion) the improving of the arterials and major collectors, 10 to 20 percent of the total mileage, to a level of service comparable with principal arterials or freeways. To a lesser degree, alternatives should reflect different physical configurations.

The goals of the state should be served by the goals and objectives of the transportation system. The objectives of the transportation system should be further developed into evaluation criteria or performance standards. Tests of alternative systems using the criteria or standards should lead to a recommended plan that best serves the goals of the state and is economically justifiable.

Finally, the planning effort is wasted unless it leads to implemented improvements. One of the major phases of the study should be work on implementation.

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Under the terms of its congressional charter, the Academy is also called upon to act as an official—yet independent—adviser to the federal government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the government.

The **National Academy of Engineering** was established on December 5, 1964. On that date the Council of the National Academy of Sciences, under the authority of its act of incorporation, adopted articles of organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the federal government, upon request, on any subject of science or technology.

The **National Research Council** was organized as an agency of the National Academy of Sciences in 1916, at the request of President Wilson, to provide a broader participation by American scientists and engineers in the work of the Academy in service to science and the nation. Its members, who receive their appointments from the President of the National Academy of Sciences, are drawn from academic, industrial, and government organizations throughout the country. The National Research Council serves both Academies in the discharge of their responsibilities. Supported by private and public contributions, grants, and contracts and by voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

The **Division of Engineering** is one of the eight major divisions into which the National Research Council is organized for the conduct of its work. Its membership includes representatives of the nation's leading technical societies as well as a number of members-at-large. Its Chairman is appointed by the Council of the Academy of Sciences upon nomination by the Council of the Academy of Engineering.

The **Highway Research Board** is an agency of the Division of Engineering. The Board was established November 11, 1920, under the auspices of the National Research Council as a cooperative organization of the highway technologists of America. The purpose of the Board is to advance knowledge of the nature and performance of transportation systems through the stimulation of research and dissemination of information derived therefrom. It is supported in this effort by the state highway departments, the U.S. Department of Transportation, and many other organizations interested in the development of transportation.

HIGHWAY RESEARCH BOARD
NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL
2101 Constitution Avenue Washington, D. C. 20418

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